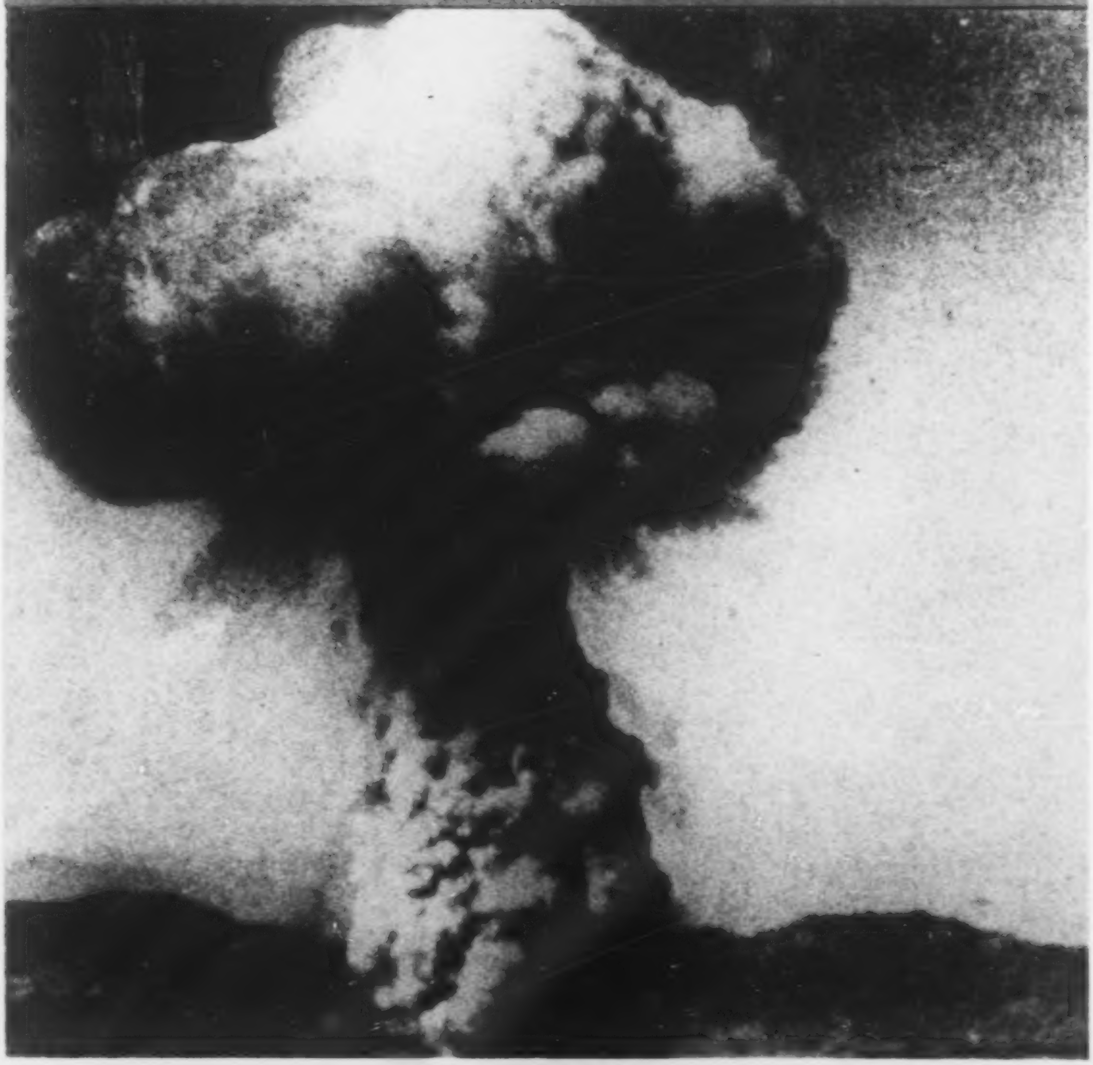
CONGRESS OF THE UNITED STATES
CONGRESSIONAL BUDGET OFFICE

OCTOBER 1991

The START Treaty And Beyond



A CBO STUDY

J932-33

THE START TREATY AND BEYOND

October 1991

The Congress of the United States
Congressional Budget Office

NOTES

Unless otherwise indicated, all years referred to in this study are fiscal years, and all costs are in constant 1992 dollars of budget authority.

Details in the text, tables, and figures of this study may not add to totals because of rounding.

The names Soviet Union and post-Soviet Union are both used in this study; the status of the new proposed name, Union of Sovereign States, was not yet clear at the time of this writing.

A list and description of the many nuclear arms agreements before START, which are mentioned throughout this study, appear in Box 1.

President Bush's September 27, 1991, initiative on nuclear weapons is fully incorporated in this study. For this reason, some of the details that appear here are different from those presented in the testimony of Robert D. Reischauer, Director of the Congressional Budget Office, before the Senate Committee on Foreign Relations on September 25, 1991.

President Gorbachev's October 5, 1991, response to President Bush's initiative was made just as this study was going to press. It is discussed in this study, but the full implications of Mr. Gorbachev's pledge to reduce Soviet strategic warheads below START ceilings are not yet clear, and are not fleshed out in CBO's analysis.

PREFACE

The size and capabilities of U.S. and Soviet nuclear forces have been the source of heated debate throughout the nuclear age. Many people have found the enormous size of these arsenals incongruous with their great destructive capacity. Others have found a very large U.S. arsenal necessary, given the difficulty of defending distant overseas interests with conventional forces alone. Still others have viewed nuclear modernization programs as bargaining chips for arms control negotiations, or as important indications of U.S. resolve in the face of Soviet militarism.

The START treaty, signed in Moscow in July 1991, is the end product of a decade-long effort to wrestle with these various perspectives. But while the treaty would accomplish some important goals, recent events of greater note have already overshadowed it. The fundamental transformation of the Soviet political body has put old debates over nuclear deterrence in a drastically new light. The nuclear debate has also been affected recently by international concern over Iraq's nuclear capabilities, and the implications for United States and coalition policy. Finally, the President's recent initiative, and Soviet President Gorbachev's response, have also introduced new ideas for arms control.

This study, prepared at the request of the Chairman of the Senate Committee on Foreign Relations' Subcommittee on European Affairs, explores the issues these developments raise. It develops and analyzes a number of possible future approaches to U.S. nuclear deterrence. In keeping with CBO's mandate to provide nonpartisan analysis, this study makes no recommendations.

The study was researched and written by David Mosher and Michael O'Hanlon of CBO's National Security Division, under the direction of Robert Hale, Bill Thomas, and Jack Mayer (formerly of CBO). O'Hanlon organized the study and focused on targeting, verification, and international politics; Mosher led the efforts on analyzing the nuclear war scenarios and missile defenses. Raymond Hall of

CBO's Budget Analysis Division prepared most of the cost analyses and helped write Chapter IV. Eugene Bryton estimated Department of Energy costs; Mick Miller coordinated the costing effort and helped write Chapter IV; Bill Myers and Barbara Hollinshead helped with costs on the B-2 and on Department of Energy cleanup, respectively. Frederick Ribe prepared Box 4.

The authors are also deeply grateful to Frank von Hippel and Frances Lussier for reviewing their work very carefully. The study is much improved thanks to their painstakingly thorough contributions. Michael Deich, Harold Feiveson, Dan Fenstermacher, Doug George, and Jim Miller provided thoughtful reviews. Michael Berger, Bruce Blair, Barry Bosworth, Matthew Bunn, Joshua Epstein, Aaron Friedberg, Clifford Gaddi, Michael Gordon, Eric Graben, Melissa Healy, Ron Lehman, Dunbar Lockwood, Peter Murrell, Lane Pierrot, John Pike, and numerous employees of the Department of Defense were also of great assistance. Of course, all responsibility for the study lies with the authors and CBO.

Paul L. Houts edited the manuscript. Chris Spoor provided editorial assistance. Cindy Cleveland and Martina Wojak typed the many drafts. Kathryn Quattrone prepared the study for publication.

Robert D. Reischauer
Director

October 1991

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SUMMARY

The United States and the Soviet Union have recently completed the Strategic Arms Reduction Talks (START) Treaty, which could enter into force sometime in the next year if ratified by the legislative bodies of both countries. The START treaty would be the first arms control accord to require actual reductions in strategic offensive forces. START's extensive verification provisions should improve each country's confidence that the other was complying with treaty strictures and increase openness between the two nuclear powers. Coupled with President Bush's September 1991 initiative and President Gorbachev's October response, it may also improve nuclear stability and safety.

START would not, however, fulfill many of the ambitions that some hold for nuclear arms control. Its mandated reductions in forces would be only about half as great as the 50 percent cuts Presidents Reagan and Gorbachev originally envisioned at Reykjavik in 1986. They would do no more than return U.S. and Soviet arsenals to their levels of 1982, when the START negotiations began. Moreover, modernizing nuclear arsenals could continue unconstrained, provided that enough older systems were retired from service to keep total deployed weapons below the specified ceilings. Nor would the President's September initiative guarantee more than modest changes in strategic modernization.

To some analysts, these characteristics of START suggest that the treaty should be only an interim step toward more sweeping arms control. That view may be reinforced if the Soviet Union seeks Western aid, continues to cooperate with the United States on foreign policy issues, and fundamentally reshapes its political system. In such a world, if the two superpowers were to continue to maintain nuclear arsenals at the levels now planned by the Administration, consisting of about 10,500 long-range warheads and another 7,500 shorter-range systems, it might strike some as highly anachronistic. Judging by their recent

actions, it would appear that Presidents Bush and Gorbachev have begun to feel this way themselves.

The START treaty could serve as a useful framework for deeper cuts in strategic weapons. For example, it might be sufficient to change some of the numerical restrictions, add one or two new types of verification provisions, and clarify any vagueness in the START treaty that becomes apparent during its first year or two. Otherwise, a post-START treaty could be based largely on START. The President made some of these points in his speech on September 27, and Mr. Gorbachev for his part has announced that the Soviet Union eventually will act as if START allowed fewer warheads than it actually does.

This study examines the effects of the START treaty and the President's initiative on the costs and capabilities of U.S. nuclear forces, should the START treaty be ratified and enter into force. The study also analyzes the effects of a wide range of options under which the United States and the Soviet Union would reduce their forces beyond those likely to follow from the proposed START treaty.

This study considers all types of nuclear forces--strategic offensive forces (which have intercontinental range), theater offensive forces (which have shorter ranges), and defensive systems--but the primary focus of analysis is strategic offensive forces. (The study does not, however, consider a number of weapons systems that have some nuclear-related roles, such as attack submarines and many other naval systems.) The analysis suggests a number of broad conclusions.

START WOULD NOT GUARANTEE LARGE BUDGETARY SAVINGS

Compared with the Administration's plan for U.S. nuclear forces submitted in February 1991, the START treaty would generate only modest savings. The United States would continue to spend approximately $50 billion per year to buy and operate its nuclear forces.

Savings would be modest largely because the Administration's nuclear plan has already been scaled back in response to the improved state of superpower relations. The Administration's current plan would reduce the number of U.S. strategic or intercontinental warheads from today's level of about 12,900 warheads to about 11,500 warheads, and scale back production of key new systems such as the B-2 bomber and Trident submarine missile system. START is unlikely to lead to additional reductions of more than about 1,000 warheads and, eventually, perhaps 150 missiles. Moreover, START would require special compliance and verification activities specific to the treaty that would add modestly to costs, reducing savings relative to what they would be without these new demands and possibly making net savings zero.

Savings from the START treaty would be considerably larger if the United States elected to reduce its weapons deployments or nuclear modernization programs in response to carrying out the treaty. Since the treaty does not require any such reductions, however, the Congressional Budget Office (CBO) thus does not assume that they would take place. Indeed, Administration officials have argued that significant nuclear modernization should accompany arms control.

Although START would not guarantee large savings, negotiations over the treaty may already have helped to codify and stabilize U.S.-Soviet relations. This improved state of superpower relations may in turn have hastened the reductions mentioned above in plans for U.S. nuclear forces and, hence, in planned costs. Compared with a plan for U.S. nuclear forces similar to that proposed by the Bush Administration in 1990, START would save an average of nearly $7 billion a year.

MODEST ANNUAL SAVINGS WOULD ACCRUE UNDER THE PRESIDENT'S INITIATIVE

On September 27, 1991, President Bush made significant changes in U.S. nuclear forces. The unilateral actions announced by the President would reduce theater warheads by about 25 percent, to a level of about 7,500. The President would also unilaterally pare some modernization plans for U.S. strategic forces but would not reduce the number of strategic warheads below the START level. The President called for negotiations with the Soviet Union that could lead to reductions in strategic warheads. Because these proposals are subject to negotiation, they are not analyzed in detail in this study. However, Mr. Gorbachev's October 5 response to Mr. Bush, which also included announcements about unilateral arms cuts, makes it appear that follow-on negotiations on strategic, theater, and missile-defense systems may take place.

Compared with the Administration's plan of early 1991, the President's unilateral initiatives would reduce nuclear-related costs by an average of about one-half billion dollars per year over the next 15 years, a cut of about 1 percent in spending on nuclear systems.

POST-START OPTIONS COULD SAVE SUBSTANTIAL SUMS

Savings could be substantially larger under some post-START options. This study examines four options intended to illustrate possible post-START treaties. The first would maintain START numerical limits, and in addition ban certain large or "heavy" missiles as well as ballistic missile-defense systems with large numbers of interceptors (see Summary Table 1). This option is one possible means of meeting the President's goal of reducing large land-based missiles with multiple warheads.

The other options are based on the assumption that, by about the year 2006, levels of U.S. and Soviet strategic warheads would be reduced to 6,000 warheads, 3,000 warheads, or 1,000 warheads per country. Total numbers of warheads per country, including those of shorter range, would be about 20,000 under both START and the first option, declining to 10,000, 5,000, and 1,000 total warheads for Options II through IV, respectively.

No large savings would result from Option I, which would keep numbers of warheads at the START level. However, adopting one of the other options could lead to substantial savings. The 6,000 strategic-warhead option could pare the budget by more than $9 billion per year over the next 15 years, compared with current plans; the 3,000 strategic-warhead option could save more than $15 billion per year.

SUMMARY TABLE 1. U.S. FORCE POSTURES AND THEIR MAIN CHARACTERISTICS IN 2006

Plan or Option	Warheads (Thousands)		Deployed Strategic Defenses[a]	Average Annual Savings Compared with Administration's Plan (Billions of 1992 dollars)
	Strategic	Theater		
Forces as of Early 1991	12.9	10.0	None	n.a.
Administration's Plan and Variation[b]				
Administration's Current Plan	11.5	7.5	GPALS, Phase I	n.a.
Administration's Plan with START	10.5	7.5	GPALS, Phase I	n.a.
Post-START Options				
I. Ban Heavy ICBMs, Limit Defenses	10.5	7.5	GPALS	2.3
II. Reduce Strategic Warheads to 6,000	6.0	4.0	GPALS, no space defense	9.3
III. Reduce Strategic Warheads to 3,000	3.0	2.0	One-half GPALS, no space defense[c]	15.5
IV. Reduce Strategic Warheads to 1,000	1.0	0	One-eighth GPALS, no space defense[c]	17.4

SOURCE: Congressional Budget Office.

NOTES: GPALS = Global Protection Against Limited Strikes; ICBMs = intercontinental ballistic missiles; Phase I = first stage of a large defense system against a ballistic missile attack; no space defense = space-based interceptors cannot be deployed.

n.a. = not applicable.

[a] All postures include the Administration's program for the Tactical Missile Defense Initiative (TMDI). The references to GPALS in the table refer not to TMDI but to the strategic components. The space-based components of GPALS mentioned in the table are brilliant pebbles interceptors.

[b] The Administration's plan is a CBO projection of likely Department of Defense plans through 2006. The "Administration's Plan with START" suggests how the Administration's plan might be modified in order to comply with the START treaty.

[c] "One-half GPALS" and "one-eighth GPALS" imply reductions of about 50 percent and 85 percent in the number of interceptor missiles per base.

Were it possible to cut total arsenals to 1,000 warheads each, net U.S. costs would decline by an average of more than $17 billion per year over the next 15 years.

In Options II, III, and IV, about half the savings would stem from reductions in costs to buy and operate strategic offensive systems. Other large sources of savings would include reductions in costs to manufacture and maintain nuclear warheads ($2.3 billion annual savings for Option IV), reduced costs associated with systems of strategic defenses ($4.3 billion annually for Option IV), and reduced costs of theater nuclear weapons ($1.5 billion annually for Option IV). The total savings are net of cost increases of up to $0.9 billion a year from verification and compliance activities under a post-START treaty.

Savings associated with the post-START options would be smaller if a decision is made to forgo any deployment of defenses. A portion of the savings associated with the options is realized because deployed strategic defenses under the options are assumed to be smaller than the Administration's planned deployment. If no defenses were deployed, savings under the options would range from nearly zero (under Option I) to $13 billion a year (under Option IV).

SUBSTANTIAL RETALIATORY CAPABILITY WOULD REMAIN

This study assumes that post-START reductions in nuclear warheads would be bilateral and to equal levels. Hence, the rough parity of strategic warheads and theater warheads that exists today between the United States and the Soviet Union would be retained in each case.

While maintaining parity is a worthy goal, the ability of the United States to deter nuclear war is the key standard against which these post-START options must be measured. Most analysts believe that deterrence depends on the capability of U.S. forces to survive a first-strike attack by the Soviet Union and still hold at risk a substantial number of important targets in the Soviet Union. Under the post-START options analyzed in this study, could surviving U.S. forces hold enough Soviet targets at risk to deter war?

Prevailing military doctrine might lead one to say no. Reportedly, U.S. nuclear war planning has identified as important potential targets approximately 21,000 sites in the Soviet Union that fall into four broad categories (see Summary Table 2). Current war plans reportedly anticipate striking as many as 8,000 of these targets. The United States would not have enough surviving warheads to conduct such a large attack under most of the post-START options, which may be of concern to military planners.

Large sets of targets have a long tradition in U.S. military planning. Since the Eisenhower days, the United States has sought to maintain nuclear forces that could withstand an attack by the Soviet Union and still retaliate against thousands of Soviet targets. The U.S. nuclear arsenal has exceeded 10,000 warheads for over three decades, and its formal nuclear war plans have called for attacking thousands of individual sites since the plans were developed in 1960.

The smaller forces available under the post-START options would, however, still leave the United States with a substantial ability to absorb an attack by the Soviet Union and then retaliate against a wide variety of targets. For example, even in the post-START option that would reduce U.S. and Soviet forces to a level of 1,000 warheads in each country, the United States could expect that hundreds of its warheads would survive a first-strike attack by the Soviet Union. With these warheads, the United States could retaliate against the smaller of the alternative sets of targets listed in Summary Table 2, or it could attack some of the targets in the medium set. For example, with 600 warheads the United States could virtually annihilate all major Soviet industries, major transportation nodes, and major fixed military infrastructure in the Soviet Union.

Alternatively, the United States could target Soviet nuclear forces as well as some command and control facilities that presumably would house some Soviet leaders. In any case, with small nuclear forces, the United States would not be constrained to retaliate against only cities in the Soviet Union, an action this country might be reluctant to undertake for moral reasons and for fear of inviting retaliation against U.S. cities.

Thus, the United States might conclude that it would have adequate deterrent capability under the post-START options in this study, even those that would result in mutual reductions of U.S. and Soviet strategic forces to levels as low as 1,000 warheads on each side. Indeed, a number of analysts and senior policymakers have recommended reducing warheads to a range of 1,000 to 3,000. Low levels of warheads may also be consistent with a world in which the United States and the Soviet Union are cooperating rather than confronting each other.

SUMMARY TABLE 2. ILLUSTRATIVE SETS OF STRATEGIC TARGETS IN THE SOVIET UNION

Category	Targets in the National Strategic Target Data Base (Estimated)	Targets in the Single Integrated Operational Plan (Estimated)	Target Set		
			Large	Medium	Small
Nuclear Forces (Counterforce)	11,000	4,000	4,000	450	0
Command, Control, Communications, and Intelligence	5,000	2,000	500	400	0
Other Military Targets					
Major depots	200	200	200	200	200
Marshaling yards	50	50	50	50	50
Major tactical aircraft bases	200	150	100	100	100
Major bridges, rail and petroleum lines	150	100	100	0	0
Major headquarters	50	50	50	50	50
Small headquarters, depots, and so forth	1,000	450	0	0	0
Industry					
Critical industry	350	250	250	250	200
Other	3,000	750	250	0	0
Total	21,000	8,000	5,500	1,500	600

SOURCE: Congressional Budget Office.

One must acknowledge, however, that adopting the more far-reaching of the post-START options would require fundamental changes in the views of this Administration, as well as those of many other important groups and individuals, about what level of nuclear deterrence is necessary in order to deter nuclear war. Equally revolutionary changes in thinking would have to take place in the Soviet Union, where some conservatives may see nuclear weapons as one of the last remaining symbols of superpower status for their country.

OTHER EFFECTS OF THE POST-START OPTIONS COULD ALSO BE POSITIVE

Even under the option that would reduce U.S. forces to 1,000 warheads, the United States would retain more strategic warheads than any country other than the Soviet Union. Thus, to the extent that nuclear weapons represent an important instrument of influence and power, the post-START options should not call into question U.S. superpower status or embolden other countries to act more aggressively in the international arena.

The Soviet Union might have more concerns in this regard, especially since key U.S. allies--Britain and France--maintain substantial nuclear forces. To minimize Soviet concerns, it may be necessary to accompany the more far-reaching options in this study with an agreement among the medium nuclear powers not to exceed their current warhead holdings, and perhaps even to cut back on those holdings.

The post-START options might offer another collateral benefit. The willingness of the United States and the Soviet Union to make major reductions in their nuclear arsenals might persuade other countries to limit their own nuclear forces. It could also convince some countries not to develop nuclear weapons. The United States and the Soviet Union would have set an important example of restraint, withdrawn their nuclear weapons from forward deployment, and bolstered their support for the Nuclear Non-Proliferation Treaty in a manner that could help them pressure other countries into abandoning their budding nuclear programs.

The post-START options could, however, raise some concerns about U.S. military capability. Some analysts argue that U.S. ability to deter conflicts in various parts of the world--often referred to as extended deterrence--can be effective only if Washington possesses some measure of real or perceived superiority in nuclear weapons vis-à-vis Moscow. Under the post-START options in this study, the United States probably would not have any substantial superiority over the Soviet Union. There are, however, reasons to believe that a much smaller nuclear arsenal would not jeopardize extended deterrence, especially if the United States remained globally active with its conventional forces.

THE EFFECTS OF DEFENSES WOULD DEPEND HEAVILY ON SOVIET REACTIONS

The Administration's plan includes a large system of defenses against missiles armed with nuclear warheads. Deployment would consist initially of a Global Protection Against Limited Strikes (GPALS) system, designed to intercept up to 200 incoming warheads, and proceed to a Phase I system designed to intercept at least 1,500 warheads.

Despite the many unresolved questions and the controversy surrounding these systems, their effectiveness would depend fundamentally on how the Soviet Union reacted to their deployment. Under some circumstances, deploying defenses might be advantageous to the United States and could add to any benefits from the START treaty. For example, deploying defenses could be of great value to U.S. and global security if both the Soviet Union and the United States were able, through technological innovations and fundamental transformations of their military doctrines, to deter nuclear war through effective defenses rather than by threatening each other with nuclear annihilation. It may have been this hope that prompted President Reagan to propose developing and deploying U.S. defenses in 1983.

Alternatively, Soviet reactions to any U.S. deployment of large-scale defenses could lead to unfavorable results. A large-scale system of U.S. defenses could, for example, cause the Soviet Union to believe that it would no longer have enough surviving or retaliatory forces of its own to deter the United States from starting a nuclear war. In that case, the Soviet Union might abrogate all existing arms control treaties limiting offensive forces and expand its arsenal to ensure a capability to overwhelm U.S. defenses. Even worse, it might adopt a "hair-trigger" strategy of launching its own missiles on receiving a warning of war. Such a policy could increase the terrible risk of nuclear war starting inadvertently during an international crisis. Perhaps most likely, the Soviet Union could deploy countermeasures to U.S. defenses that could negate their effectiveness, or possibly lead to an offense-defense arms race.

More limited defensive systems, such as the Administration's proposed GPALS, could offer some advantages while posing fewer risks than large-scale defenses. Although they presumably would not be as effective as a large-scale system, limited defenses could provide some protection for the United States against an accidental or unintentional launch and against the forces of a hostile country that could develop a few long-range ballistic missiles at some point in the future. Yet, systems of such limited capability would not be large enough to prevent the Soviet Union from retaliating during a second strike, and hence might not create the problems discussed earlier.

VERIFICATION AND SURVIVABLE FORCES WOULD MINIMIZE THE RISKS OF BREAKOUT

Presumably, a bilateral treaty between the United States and the Soviet Union would codify any post-START option. Could the United States monitor Soviet behavior enough to be confident that Moscow was in compliance with such a treaty?

No verification procedures can ever be perfectly effective, and noncompliance cannot be ruled out under any arms control agreement. Thus, CBO cannot conclude that either the START treaty or a post-START treaty would be clearly verifiable. That conclusion depends on a judgment about how much uncertainty is acceptable.

The United States could, however, minimize the risks of noncompliance by negotiating and instituting additional procedures beyond those now included in the START treaty. These steps, which might be especially appropriate if a post-START treaty called for deep reductions in warheads, could include limiting and monitoring all nondeployed missiles, warheads, and fissile materials.

Moreover, the mobile nature of the forces that the United States is assumed to maintain in a post-START world would limit the military risk associated with cheating. Because mobile systems are difficult for an attacker to locate and destroy, even large numbers of extra enemy warheads would not markedly reduce the number of U.S. warheads that would survive the enemy attack. For example, even if the Soviet Union could clandestinely maintain 5,000 warheads under a treaty that limited each side to 1,000 warheads, the number of U.S. warheads that could survive a Soviet first-strike attack would not be greatly reduced. Hence, even in the face of egregious duplicity, a substantial fraction of U.S. warheads should remain available for retaliation. The only drawback is that maintaining forces of this nature costs more than one might initially expect under deep cuts in nuclear arms.

SUMMING UP

In deciding to go to war against Iraq, President Bush called on Americans and other peoples to join in building what he called a new world order--a system of international behavior that would replace Cold War tendencies with more respect for the rules of international law. Nuclear arms control of the type envisioned in this study's post-START options might play a role in such a broad reshaping of U.S. foreign policy. The options would be consistent with a world that focused more on cooperation than confrontation. These options could also foster a much more secure environment by providing incentives for other important types of arms control, perhaps including limits on nuclear proliferation. Nuclear arms control might also free up U.S. fiscal resources on the order of $15 billion annually. These resources could be put to uses that would improve both domestic and foreign policy.

CHAPTER I

INTRODUCTION

At the time of this publication in early October 1991, Presidents Bush and Gorbachev have made sweeping changes in short-range nuclear weapons, and significant changes in some dimensions of their countries' long-range nuclear forces. In addition, the United States and the Soviet Union have recently concluded and signed the Strategic Arms Reduction Talks (START) Treaty. Should both sides ratify the treaty, it could enter into force sometime in 1991 or 1992. If so, it would be the fourth major superpower arms control agreement limiting offensive nuclear systems of the last two decades.

In the 1970s, the Strategic Arms Limitation Talks (SALT) produced the Interim Agreement, the 1972 Anti-Ballistic Missile (ABM) Treaty limiting missile defenses, and later the SALT II treaty. (SALT II was never ratified, though both countries observed its main stipulations during the entirety of its originally intended lifetime.) The Intermediate-Range Nuclear Forces (INF) Treaty was signed and ratified in 1987, and has now been fully carried out (see Box 1).

The START treaty would accomplish several important goals. It would be the first treaty to require reductions in deployed strategic offensive forces--that is, forces that can attack targets at intercontinental range. (The INF treaty required global elimination of all ground-launched missiles with ranges of between 500 and 5,500 kilometers.) The nominal ceiling of 6,000 deployed strategic weapons per country would effectively reduce the long-range, nuclear-delivery capability of each country by about 20 percent to 35 percent--once special counting rules for long-range bombers are taken into account. START would place explicit limits on the huge Soviet SS-18 intercontinental ballistic missiles (ICBMs), whose capabilities have concerned U.S. policymakers for over a decade. Conversely, it would apply relatively lenient treatment to warheads carried on bombers--delivery systems that may

BOX 1
Agreements Affecting Nuclear Arms Involving the United States Before START

Hot Line Agreement (Signed in 1963): Established direct communications link between the United States and the Soviet Union.

Limited Test Ban Treaty (1963): Banned nuclear testing in the atmosphere, outer space, and the oceans.

Treaty on Outer Space (1967): Banned nuclear weapons in space.

Protocol to the Latin America Nuclear Free Zone Treaty (1968): Banned nuclear weapons in Latin America and the use of nuclear threats by nuclear powers against signatories to the treaty.

Nuclear Non-Proliferation Treaty (1968): Called on nonnuclear states not to acquire nuclear weapons, on nuclear powers to seek agreement to end all nuclear testing and to move toward nuclear disarmament, and on nuclear powers to share nuclear energy technologies with nonnuclear signatories provided that safeguards on the technologies are used.

Seabed Treaty (1971): Banned placing nuclear weapons and associated equipment on seafloors beyond 12-mile limit.

Hot Line Agreement (1971): Improved 1963 Hot Line Agreement with satellite links and multiple terminals.

Agreement to Reduce Nuclear Risk (1971): Pledged United States and Soviet Union to share information on accidents and to improve safety.

Strategic Arms Limitation Talks (SALT) I Interim Agreement (1972): Froze number of U.S. and Soviet deployed launchers for intercontinental and submarine-launched ballistic missiles.

SALT I Anti-Ballistic Missile Treaty (1972): Together with 1974 Protocol, limited ballistic missile defenses to a single site.

SALT I Understanding on Basic Principles (1972): Obligated United States and Soviet Union to share global responsibility for peacekeeping and avoid competition.

Threshold Test Ban Treaty (1974): Limited underground nuclear tests to a yield of 150 kilotons; called for minimal testing and an eventual test ban.

Peaceful Nuclear Explosions Treaty (1976): Extended limits on nuclear testing to peaceful nuclear explosions.

SALT II Treaty (1979): Limited all U.S. and Soviet strategic launchers.

Intermediate-Range Nuclear Forces (INF) Treaty (1987): Instituted global ban on U.S. and Soviet medium-range missiles, with on-site inspection provisions.

contribute to stability because they can be recalled after being launched.

In addition, the START treaty would include significant provisions allowing on-site inspection at declared military facilities and at sites suspected of illicitly holding equipment limited by the treaty. Other notable verification provisions would allow continuous and permanent monitoring of some missile-production sites, and require each country to share its missile-test data with the other by banning any encoding of radio-signal "telemetry" that missiles send out during testing.

Finally, START would strike a compromise on the issue of defenses against missile attack. The treaty would neither explicitly reaffirm the Anti-Ballistic Missile Treaty of 1972, nor interfere directly with the U.S. Strategic Defense Initiative and similar Soviet programs. The Soviet Union has gone on record in the START treaty as stating that it reserves the right to exceed START ceilings on weapons should the United States choose to abrogate the ABM treaty and deploy a significant missile-defense system. Still, President Gorbachev's October speech suggests that the Soviet Union may prove flexible on the subject of limited defenses.

All of these understandings were reached before the historic unsuccessful Soviet coup in August 1991. However, the United States must now judge all of this detail on the nature of the START treaty, not only in the context of a reformist Soviet Union but also against the backdrop of the failed hard-line coup and the astounding sea change that is taking place in all aspects of Soviet life.

For these reasons, even assuming that ratification occurs quickly, a START treaty is unlikely to fulfill the aspirations of many people for nuclear arms control. For example, START's numerical ceilings on weapons, though lower than today's levels, would not even achieve the warhead reductions of 50 percent that Presidents Reagan and Gorbachev originally envisioned at Reykjavik in 1986, when the Cold War was alive and well. Indeed, the treaty would do little more than return the superpowers to the levels of strategic nuclear armament that existed when START negotiations began in 1982. President Bush's September 1991 initiative would reduce shorter-range nuclear weapons significantly, but would not reduce strategic arsenals further--though his initial proposals for further negotiated cuts in strategic arms, and the response they evoked from President Gorbachev in his October speech, could prove to be the first steps in a process that may lead to deeper cuts.

The START treaty has other limitations as well. Those warheads and missiles that were in excess of treaty ceilings would have to be retired from active service, but they would not need to be destroyed. Even more significant, apart from limitations on the SS-18 missile and bans on new types of large or "heavy" missiles, the treaty would place no quantitative or qualitative restrictions on modernizing weapons. New weapons could be built and deployed in any number, as long as older ones were retired to keep the total number of deployed forces below the ceilings specified in the treaty. Increasingly capable superpower nuclear forces would remain aimed at each other. They could help perpetuate a superpower arms competition that could endanger progress in U.S.-Soviet relations made on other fronts, preserve a role for Soviet hard-liners in future Kremlin policymaking, and keep a plethora of nuclear weapons strewn across the politically and militarily volatile landscape of the Soviet Union.

A number of analysts and policymakers regard such an ongoing nuclear arms competition as obsolete, wasteful, and dangerous. In their view, whether or not a rationale existed for highly redundant and destructive nuclear arsenals during the Cold War, it would be ironic and perplexing if the United States and the Soviet Union continued to aim thousands of the deadliest weapons ever invented at each other at this stage in their relations. The two states have learned to get along in almost all types of interaction, and in many cases they have indeed worked together. The Soviet Union supported U.S. and coalition policy during the Persian Gulf War, and has cooperated with Washington in regional peacemaking efforts in theaters such as Southwest Africa and the Middle East. Both countries also expanded their joint efforts to control the spread of weapons to the Third World.

Finally, depending on what occurs in the wake of the failed August putsch, Soviet claims to superpower status may seem more and more tenuous. Under such circumstances, the premise that the United

States and the Soviet Union--or its successor state--need view each other as adversaries may totally change.

Certainly, progress at the START talks may have helped to improve U.S.-Soviet relations, thereby contributing to some of the unilateral cuts in defense spending that the United States has made in recent years. But the START treaty itself would not significantly reduce the defense budget. Compared with the Administration's current plan for nuclear weapons, START would have little impact on the defense budget. It might reduce the annual costs of U.S. nuclear forces modestly over the next 15 years--depending on, among other things, the manner in which the Department of Energy's infrastructure is reconfigured in the future and on the manner in which verification and compliance activities are undertaken.

In fact, because of relatively high costs of verification and compliance during the first few years the treaty is carried out, START might not produce any savings whatsoever for several years. The President's initiative would save some money, but, overall, spending on nuclear forces would probably remain nearly constant at almost $50 billion per year, as measured in 1992 dollars--more than the entire military budget of any country in the world besides the United States and the Soviet Union. Moreover, strategic forces could consume an increasingly large share of total Pentagon spending during a period of declining defense budgets, President Bush's September 1991 initiative notwithstanding.

The START treaty cannot solve all nuclear arms problems confronting the superpowers, especially since it was conceived and begun during an intensive period of the Cold War. Nevertheless, the limited scope of START has spurred some analysts to argue for a post-START treaty that would make more far-reaching changes in nuclear forces, including substantially reducing the number of warheads. The Bush Administration apparently now has some interest in such ideas, though the extent of its interest is by no means clear at the time of this writing. The Soviet Union has shown interest in deeper cuts as well, evidenced in Soviet President Gorbachev's October 5 pledge to reduce Soviet forces below START ceilings and his call for negotiations to reduce strategic forces further.

Although a post-Soviet country may not retain superpower status indefinitely, the huge military forces remaining within the Soviet Union call for a pragmatic approach to managing reductions. The long tradition of U.S.-Soviet bilateral arms control, the template the START treaty provides, and the overwhelmingly large sizes of U.S. and Soviet nuclear arsenals all suggest that a bilateral framework may remain the best mechanism for the next stage of nuclear arms control.

In large part, the START treaty could serve as the basis for a subsequent accord, since START contains highly sophisticated and carefully worked out understandings on matters such as verification, definition of new weapons types, reductions in the number of warheads that individual ballistic missiles carry, and allowances for "dual-use" systems that can carry either conventional or nuclear warheads. Not only could a post-START treaty save great amounts of money, but it also could help defuse the nuclear arms competition, improve safety, allow the superpowers to put more pressure on would-be nuclear proliferators, and not least improve the stability of U.S.-Soviet military and political relations.

Against all of these possible benefits, however, one must weigh the risks of reducing warhead numbers. Most notably, with fewer warheads the United States would have less ability to threaten a wide range of targets with nuclear forces. At some point, presumably, further reductions in the flexibility and capability of nuclear forces might weaken deterrence. In addition, the number of warheads on either side that could survive an all-out first strike by the other might become imprudently low--to the point where, in a crisis, each country might feel an incentive to attack first before it was attacked itself and largely disarmed. Finally, the dictates of military reason aside, both the United States and the Soviet Union--or its successor--may prove reluctant to scale back appreciably one of the great symbols of their superpower status. The substantial sizes of British, French, and Chinese forces reinforce this reality. These types of concerns are found both in the Soviet Union and in the United States, and they may well prove obstacles to any serious move toward deep cuts in nuclear weaponry.

CHAPTER II

TARGETING, DOCTRINE, AND DETERRENCE

What does it take to deter nuclear war? This question is partly military, partly political, and partly philosophical. Accordingly, a wide range of answers is possible. In a similar vein, this study develops and analyzes an array of options for U.S. nuclear forces. Under the various options, warheads on strategic or intercontinental missiles and aircraft range from today's level of about 12,900 warheads to as few as 1,000 warheads. Total nuclear warheads (including those that can cover less than intercontinental ranges) vary from about 23,000 warheads today down to the 1,000-warhead level. Missile defenses also vary widely.[1]

In all notable theories of what constitutes adequate deterrence, one finds a single recurrent element--to deter war, a country must have secure second-strike forces. With such forces, capable of surviving an all-out attack by an adversary and credibly threatening significant damage in a reprisal, a country should be able to deter any other country contemplating nuclear aggression against it. But few analysts agree on exactly what level of damage a retaliatory strike would have to be capable of inflicting in order to act as an effective deterrent.

In addition, ever since the Eisenhower Administration and its "New Look" philosophy of nuclear deterrence, the United States has felt that the North Atlantic Treaty Organization (NATO) alliance's conventional capability alone could not counter large Soviet armies in Europe. This judgment led policymakers to believe that large and capable U.S. nuclear forces--ideally superior in some regards to those of the Soviet Union--would be needed as well. This perceived need to deter conventional attacks with nuclear weapons has also influenced U.S. nuclear doctrine, though the concern has diminished in importance with the recent and dramatic transformation of the Soviet Union.

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[1] For support for large reductions in numbers of warheads, see Committee on International Security and Arms Control, National Academy of Sciences, *The Future of the U.S.-Soviet Nuclear Relationship* (Washington, D.C.: National Academy Press, 1991); Michael M. May, George F. Bing, and John D. Steinbruner, *Strategic Arms Reductions* (Washington, D.C.: Brookings Institution, 1988); Harold Brown, "Navigating the Security Sea Change," *Arms Control Today* (May 1990), pp. 3-7; John D. Steinbruner, "The Effect of Strategic Force Reductions on Nuclear Strategy," *Arms Control Today* (May 1988), pp. 3-5; Harold A. Feiveson and Frank N. von Hippel, "Beyond START: How to Make Much Deeper Cuts," *International Security* (Summer 1990), pp. 154-180; and Richard L. Garwin, "A Blueprint for Radical Weapons Cuts," *Bulletin of the Atomic Scientists* (March 1988), pp. 10-13. The Department of Energy, in developing its plans for the twenty-first century, apparently is taking such ideas seriously; the assumption has been made that warhead levels could be reduced by 30 percent to 85 percent relative to current inventories. See R. Jeffrey Smith, "U.S. Expected to Reduce Number of Nuclear Targets," *Washington Post*, April 19, 1991, p. A17.

The requirements of deterrence may be partly unknowable--different countries may have different values, may change their policies over time, and could behave differently from one situation to another. But various military and historical considerations can provide benchmarks for determining these requirements.

A THUMBNAIL HISTORY OF OFFICIAL U.S. VIEWS ON STRATEGIC DETERRENCE AND TARGETING

Before 1950 or so, there were not enough warheads in the U.S. nuclear arsenal to envision anything but World War II-type "strategic bombardment" campaigns against cities--as embodied in the war plans code-named BROILER, FROLIC, HALFMOON, and TROJAN. In the late years of the Truman Administration, however, targets began to be organized into counternuclear, counterconventional, and countersocietal categories. The corresponding missions for nuclear forces were designated as BRAVO, ROMEO, and DELTA--for blunting Soviet nuclear retaliation, retarding Soviet conventional military capability, and destroying Soviet urban and industrial targets. Deployments of tactical nuclear weapons were begun at this time as well.

By the time Eisenhower reached office, more than 1,000 warheads were in the U.S. nuclear arsenal. The number increased to about 18,000 by the beginning of the Kennedy Administration. Thus, since the 1950s, large nuclear forces have been deployed with a broad range of capabilities and on a broad array of weapons platforms. In fact, for the last four decades, United States nuclear doctrines and war plans have displayed a great deal of continuity and consistency.[2]

For example, today's "counterforce" strategy, which would lead the United States to accord high priority to attacking Soviet nuclear forces under most scenarios for nuclear war, actually bears a great resemblance to General Curtis LeMay's preemptive attack plans of the 1950s. Today's strategic plans also resemble those developed under Secretary of Defense Robert McNamara, despite the rhetorical emphases on "mutually assured destruction" that both the Kennedy and Johnson Administrations were prone to make on occasion. And the flexibility to attack a wide variety of targets that is found in today's Single Integrated Operational Plan (SIOP)--as well as in NATO's "Flexible Response" policy, Korean nuclear policy, and naval nuclear doctrines--is not dissimilar to the Eisenhower Administration's emphasis on unpredictability and "asymmetrical response" that was associated with its defense policy nicknamed the New Look. Many of the modifications that have taken place in strategy and war plans have been marginal in importance, such as the Carter and Reagan Administrations' efforts to target Soviet leadership more than had been the case previously.

General David Jones, when Chairman of the Joint Chiefs of Staff in 1979, underscored this historical continuity in U.S. war plans.[3]

> I do not subscribe to the idea that we ever had [mutually assured destruction] as our basic strategy. I have been involved with strategic forces since the early 1950s. We have always targeted military targets . . . when I was out in the field, in Washington you would hear a lot of rhetoric about different strategies. We followed orders, but basically, the strategy stayed the same in [implementing] targeting.

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[2] For discussions of the evolution of U.S. nuclear doctrine, see, for example, Lawrence Freedman, *The Evolution of Nuclear Strategy* (New York: St. Martin's Press, 1981), pp. 22-24; David Alan Rosenberg, "The Origins of Overkill: Nuclear Weapons and American Strategy, 1945-1960," in Steven E. Miller, *Strategy and Nuclear Deterrence* (Princeton: Princeton University Press, 1984), pp. 113-181; John Lewis Gaddis, *Strategies of Containment* (New York: Oxford University Press, 1982), especially pp. 145-163.

[3] General David C. Jones, Chairman, Joint Chiefs of Staff, Hearings before the Committee on Armed Services, United States Senate, 96:1 (July 23-26, 1979), pt. I, p. 170.

In short, the old French saw sums it up: the more that changes, the more it is the same thing.

Although there has been a good deal of continuity in the basic nature of war plans, the sizes of the National Strategic Target Data Base and of the Single Integrated Operational Plan have grown considerably over the years--even after the Eisenhower Administration's major buildup. The first SIOP, finished in 1960, reportedly contained roughly 3,500 warheads to strike a total of about 2,600 sites; about 1,500 locations in the National Strategic Target Data Base were left untargeted.[4] During the next 30 years, the number of warheads available for attack, and thus the size of the SIOP, increased appreciably--more than tripling from its original size.

The current Administration's views are presumably embodied in today's U.S. war plans. Although its details are highly classified, the SIOP apparently requires that the United States be able to attack a broad range of target categories and subcategories. Such an attack could occur after the United States had absorbed a Soviet first strike, after it had detected early signs that such an attack was beginning, or even in response to a Soviet conventional military operation somewhere. Although the Bush Administration bears responsibility for current U.S. war plans, it does not appear to hold views on the subject of nuclear targeting that are fundamentally different from those of its predecessors or from many Democratic and Republican Members of the Congress.

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4. Rosenberg, "The Origins of Overkill," pp. 116-117; Desmond Ball, "The Development of the SIOP, 1960-1983," in Desmond Ball and Jeffrey Richelson, eds., *Strategic Nuclear Targeting* (Ithaca: Cornell University Press, 1986), pp. 66-70. The Ball article refers to a memorandum for President Kennedy from the Office of the Secretary of Defense, written in 1962 and projecting a list of targets for the Soviet bloc for 1969. A total of 1,860 targets were to be struck by 3,253 warheads. Of the 1,860 targets, 492 were considered high-urgency, soft strategic nuclear targets; 365 were considered high-urgency, hardened strategic nuclear targets; 610 were listed as moderate-urgency, soft strategic nuclear targets; 183 were listed as moderate-urgency, hardened strategic nuclear targets; and 210 were labeled urban-industrial sites. Apparently, no OMT--other military targets--were included, at least not in this particular memorandum.

Types of Targets

Reportedly, the United States' plans for strategic nuclear war include four major categories of Soviet targets: offensive nuclear forces and defensive forces that protect the Soviet Union against nuclear attack; other military targets (OMT); assets that provide command, control, communications, and intelligence (C^3I), including facilities where the Soviet political and military leadership might be located in peacetime or wartime; and factories and other economic assets that make up the Soviet industrial base.

The first category of targets, offensive and defensive nuclear forces, contains what are commonly referred to as "counterforce" targets. They include all of the Soviet Union's long-range nuclear weapons and delivery systems, as well as radar systems and surface-to-air missiles used for warning and for air and missile defense. The goals of targeting these forces are to ensure that U.S. nuclear forces could reach the interior of the Soviet Union and to limit--to whatever degree may be possible--the damage that enemy nuclear weapons could inflict on the United States and its allies in reprisal.

Other military targets--such as conventional military forces in the field, supply depots, troop garrisons, airfields, large tactical radar sites, and supply lines--make up a second category of targets. The United States might destroy them to weaken the Soviet Union's ability to wage conventional war, especially in Europe.

A third category of targets includes facilities that provide the wherewithal for command, control, communications, and gathering intelligence information. These facilities could be targeted at the tactical, theater, and nationwide levels in order to unravel the cohesiveness of Soviet military operations. Some military analysts think that Soviet leaders should also be targeted.

Finally, the United States might attack the industrial and economic base of the Soviet Union, the fourth category of targets, for either of two reasons: to curtail the Soviet war industry or to inhibit long-term Soviet economic recovery after a war. Apparently, the United States placed much more emphasis on the second of these rationales for industrial targeting in its strategic plans of the 1960s and 1970s than it does in today's plans.[5]

In addition, though Soviet population centers are not targeted explicitly in current war plans, nearly any nuclear exchange would catastrophically affect them. Extremely harmful, for example, would be long-range radioactive fallout from explosions whose large "fireballs" touched the ground, thereby contaminating soil that would be swept into the atmosphere and later fall back to Earth. More immediately, the proximity of many population centers to Soviet industry and military infrastructure would result in horrific damage to population centers from the blast, heat, and fire of nearby explosions.

Clearly, the possibility remains that a sufficiently desperate country might resort to threatening or attacking an adversary's cities deliberately. The locations of the cities certainly are well known, and bombers and missiles can be quickly retargeted. For now, the United States and the Soviet Union seem unlikely to resort to such techniques--though, as noted earlier, the realities of nuclear explosive power blur the practical distinctions between military, economic, and population targeting.

The Soviet Union's extensive efforts to build some semblance of shelter for its population and industry over the last few decades would not mitigate this situation very much. Harold Brown, when Secretary of Defense, estimated that only a small portion of the Soviet urban population and Soviet industry could be sheltered against nuclear attacks.[6] Moreover, shelters pose their own problems--disposing of corpses and human waste, overcrowding, disease, and shortages of food, water, and uncontaminated air.

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[5] Desmond Ball and Robert C. Toth, "Revising the SIOP: Taking War-Fighting to Dangerous Extremes," *International Security* (Spring 1990), pp. 65-92.

[6] Department of Defense, *Annual Report to the Congress: Fiscal Year 1981* (1980), pp. 77-79.

Numbers of Targets

Reportedly, the National Strategic Target Data Base (NSTDB) includes about 21,000 targets (see Table 1). The Congressional Budget Office (CBO) derived a breakdown of this aggregate number by piecing together information contained in scholarly articles, official publications of the Department of Defense, and memorandums the U.S. Army provided to CBO. The results suggest that more than half the targets represent Soviet nuclear systems, both offensive and defensive. The remainder of the targets are within the categories of command and control, other military targets, and industry.

It is useful to distinguish between targets, aim points, and allocations of warheads. Targets are the building blocks of the war plans--the sites that may have to be destroyed. Two or more targets, however, could be located closely enough together to be assigned a single aim point for targeting purposes--in technical parlance, a single designated ground zero (DGZ). Because of this possibility, a given country's plans have fewer aim points or DGZs than targets. But, as a result of the imperfect reliability of nuclear delivery vehicles and nuclear weapons themselves, some highly valuable sites may be targeted with more than a single weapon to increase the damage expectancy for each.

Warheads Required

The United States does not plan to attack every target listed in the National Strategic Target Data Base (see the first column of Table 1). According to some reports, in an all-out nuclear war, the U.S. Single Integrated Operational Plan calls for attacking approximately 6,500 to 9,000 individual aim points in the Soviet Union with 10,000 to 12,000 warheads. In all likelihood, the SIOP has been scaled back to the low end of these ranges in response to the dissolution of the Warsaw Treaty Organization, and it may be trimmed again because of changes in the composition of the Soviet Union itself. In particular, about 1,000 targets were apparently removed from the SIOP during a recent targeting review by the Bush Administration and perhaps another 2,000

TABLE 1. ILLUSTRATIVE SETS OF STRATEGIC TARGETS IN THE SOVIET UNION

Category	Targets in the National Strategic Target Data Base (Estimated)	Targets in the Single Integrated Operational Plan (Estimated)		Target Set	
			Large	Medium	Small
Nuclear Forces (Counterforce)					
Silos and launch centers	1,500	1,500	1,500	100	0
Mobile missile launch points and garrisons	7,500	1,500	1,500	50	0
Bomber and submarine bases	30	30	30	30	0
Antiballistic missile radar systems and large phased-array radar systems	20	20	20	20	0
Surface-to-air missile system sites	1,000	500	500	100	0
Interceptor bases	250	150	150	50	0
Bomber dispersal bases	100	50	50	0	0
Interceptor dispersal bases	300	100	100	0	0
Theater nuclear weapons and storage sites	300	150	150	100	0
Command, Control, Communications, and Intelligence					
Major fixed sites	100	100	100	100	0
Major mobile sites	25	25	25	25	0
Alternative leadership sites	1,500	250	100	100	0
Other	3,375	1,625	275	175	0

(Continued)

during a second review. Moreover, some Soviet facilities in the OMT and industrial categories, certain conventional military assets of the East European states, and many targets in the non-Russian Soviet Union may have been removed from the National Strategic Target Data Base and the SIOP.[7]

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[7] See Patrick E. Tyler, "Air Force Reviews 'Doomsday' Plan," *Washington Post*, July 11, 1990, p. A17; R. Jeffrey Smith, "U.S. Expected to Reduce Number of Nuclear Targets," *Washington Post*, April 19, 1991, p. A17; Robert C. Toth, "U.S. Scratches Nuclear Targets in Soviet Bloc," *Los Angeles Times*, April 19, 1991, p. A1; R. Jeffrey Smith, "U.S. Trims List of Targets in Soviet Union," *Washington Post*, July 21, 1991, p. A1; Ball and Toth, "Revising the SIOP."

TABLE 1. Continued

Category	Targets in the National Strategic Target Data Base (Estimated)	Targets in the Single Integrated Operational Plan (Estimated)	Target Set		
			Large	Medium	Small
Other Military Targets					
Major depots	200	200	200	200	200
Marshaling yards	50	50	50	50	50
Major tactical aircraft bases	200	150	100	100	100
Major bridges, rail and petroleum lines	150	100	100	0	0
Major headquarters	50	50	50	50	50
Small headquarters, depots, and so forth	1,000	450	0	0	0
Industry					
Major military production centers	100	60	60	60	60
Other critical war industry	250	190	190	190	140
Other	3,000	750	250	0	0
Total	21,000	8,000	5,500	1,500	600

SOURCE: Congressional Budget Office based on information from various editions of *Soviet Military Power*, the U.S. Army, and other sources.

However, there are limits to how far these changes are likely to reduce the SIOP. For one thing, a more hostile Soviet Union could theoretically reclaim some of these military assets at some future date, at which point they would rejoin the target set. Unlikely as this scenario may now seem, a Soviet occupation of Eastern Europe nevertheless may be the most plausible path to a nuclear crisis between the superpowers and thus may be highly appropriate to SIOP planning. Second, the NSTDB reportedly contains thousands of sites that are not targeted today, but that the military might like to target if warheads could be allocated to them. Finally, quite possibly many of the East European targets at issue were never included in the SIOP because they were envisioned for targeting by theater forces in Europe.

In the event that it absorbed a first strike by the Soviet Union before beginning its own attack, the United States might have fewer than 10,000 to 12,000 warheads available. The large target set shown in Table 1 illustrates how the United States might choose to use its warheads under such circumstances.

In the future, it may be possible to reduce the number of sites targeted by nuclear weapons without any fundamental change in sets of targets. As delivery systems become increasingly accurate and conventional warheads become increasingly lethal, some of the targets that are to be attacked--particularly "soft" sites that have not been specially hardened to withstand a nuclear attack--could be attacked with conventional rather than nuclear munitions.[8] This statement applies both to strategic and to tactical targets. Targets in the OMT and industrial categories might be the most logical candidates for such attacks, since they are generally fairly soft and are often located near population centers. Since targets in the OMT and industrial categories number in the thousands, it might be possible to reduce demands on nuclear forces substantially in this manner.

The Administration, however, apparently still believes--as do many military officials--that many thousands of targets must be held at risk with nuclear warheads to achieve deterrence. In a number of cases, a single nuclear warhead could attack several targets that are located close together. Nevertheless, attacking thousands of targets in a second strike would require a large inventory of warheads--particularly because the United States could expect to lose a significant portion of its warheads during a Soviet first-strike attack (see Chapter V of this study).

In 1990, General John Chain, then Commander of the Strategic Air Command, offered a concise explanation of these views. Commenting on the limits on warheads in the proposed START treaty, which would permit the United States to deploy no more than 4,900 warheads on ballistic missiles, Chain observed that "forty-nine hundred missile-carried warheads are not enough to destroy the Soviet Union."[9] Chain emphasized that the B-2 bomber--which would receive favorable treatment under the warhead counting rules in the START treaty and thus permit the United States to have a larger strategic arsenal under START than it would otherwise--is essential to U.S. security and deterrence, and that START might not be desirable without it.

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[8] Personal communication from Bruce G. Blair of the Brookings Institution.

[9] Bruce Van Voorst, "America's Doomsday Machine," *Time* (July 16, 1990), p. 19.

To the extent that views such as Chain's are reflected in U.S. war plans, the United States presumably would prefer not to absorb a first strike before launching its own weapons. In other words, war planners may have based much of their work on the assumption that, in the event of war, the United States would either preempt a Soviet attack or launch U.S. weapons when warned by electronic sensors that a Soviet attack was beginning. Otherwise, the United States might have fewer than 4,900 warheads at its disposal (again, see Chapter V).

OTHER VIEWS ON DETERRENCE

Not surprisingly, for all of this historical continuity in war plans, at times there has been vociferous opposition to U.S. nuclear doctrines and war plans. Opponents include some analysts who advocate modest change in U.S. doctrine and others who argue for more drastic shifts.

Advocates of Change

Some experts accept the basic categories of nuclear targets; they hold, however, various views on which subcategories should be included, how many targets should be included in each, and the degree of redundancy with which they must be attacked. Their comments suggest that slightly different approaches to constructing war plans might change the SIOP considerably. In the words of former Pentagon official Frank Gaffney, "In the final analysis, it is a more subjective exercise than it might appear at face value." Former U.S. arms control negotiator Spurgeon Keeny was more precise: "You could in fact carry out the same declaratory military policy with one-half or one-quarter of the weapons in the war plan. . . .There is a tremendous redundancy in putting multiple warheads on secondary or tertiary targets . . . ."[10]

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[10] See David J. Lynch, "Nitty-Gritty of Nuclear Targeting Draws Scrutiny," *Defense Week* (April 16, 1990), pp. 1 and 3.

Other experts have gone well beyond these moderate arguments for change and advocated sweeping overhauls in U.S. and Soviet approaches to nuclear deterrence. Harold Brown suggested that the United States might reduce its strategic forces to as few as 1,000 warheads. Former nuclear weapons designer Richard Garwin, Soviet President Gorbachev's science advisor Yevgeny Velikhov, and others have also advocated greatly reduced levels.[11] In general, however, these individuals have not yet laid out detailed blueprints for new force postures and targeting doctrines.

Even General Chain--a strong advocate of a large, modern, and multifaceted nuclear force posture--made an argument that may implicitly call into doubt the basic logic of current war plans. General Chain was discussing Soviet SS-24 and SS-25 ICBMs, which are mobile missiles that are designed to be dispersed over wide areas and so would be difficult to detect and destroy. The general said that: "One of [the Soviet legislators] took great umbrage and said, 'Our SS-24s and SS-25s are defensive,' and I said, 'I couldn't agree more, I don't have any problem with you having SS-24s and SS-25s. I think that's healthy, because there's no way I can attack them bolt out of the blue and I want to be in the same position on our side.'"[12] Yet, the current SIOP *would* devote many warheads to attacking SS-24s, SS-25s, and other Soviet nuclear forces--a mission that may, as Chain's comments suggest, be either pointless or dangerous.

Warhead numbers even lower than 1,000 have been discussed. For example, Herbert York, a nuclear weapons scientist at Livermore Laboratories for many years, has recently argued that world leaders definitely should not have the capacity to inflict more damage than the tremendous amount World War II caused--and thus 100 warheads on each side might be the proper goal for arms control. President Kennedy's former national security advisor, McGeorge Bundy, clearly articulated the views of many of those who advocate having far fewer warheads:[13]

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[11] Fred Hiatt, "Soviet Official Questions Nuclear Arsenal's Security," *Washington Post*, August 28, 1991, p. A1.

[12] Patrick E. Tyler, "SAC Chief Wants B-2, Mobile ICBM," *Washington Post*, March 6, 1990, p. A8.

[13] McGeorge Bundy, *Danger and Survival* (New York: Random House, 1988), p. 589.

> Given the warheads currently deployed, just one incoming strategic warhead on just one strictly military target--a missile silo perhaps, or a submarine base--would be the worst event for either government since World War II. Ten warheads on ten such targets would be much more than ten times worse, presenting not only immediate and hideous devastation, but questions of the utmost urgency and foreboding about the next decisions of both sides. A hundred warheads, on no-matter-what targets, would be an instant disaster still more terrible. A thousand warheads would be a catastrophe beyond all human experience. . . . As I put it almost twenty years ago, "There is no level of superiority which will make a strategic first strike between the two great states anything but an act of utter folly."

These arguments in favor of small nuclear forces are consistent with analytic estimates of how much damage nuclear war would cause. For example, former Secretary of Defense Robert McNamara calculated that as few as 200 one-megaton nuclear warheads or their equivalent would be sufficient to kill up to 25 percent of the Soviet population and destroy about 50 percent of Soviet industrial capacity.

More recent estimates of casualties resulting from nuclear attacks against the United States or the Soviet Union are even higher. The casualties would result from a combination of radioactive fallout and the immediate effects of explosions. In particular, one study calculated that as few as 100 warheads could cause up to 77 million deaths if targeted at or near cities. It is worth quoting the authors of this study here:[14]

> In a previous article, we presented estimates of the civilian casualties that would result from a Soviet strategic counterforce attack on the U.S. involving approximately 3,000 nuclear explosions. We found that 12-27 million Americans would die and that altogether 23-45 million would suffer lethal or serious non-lethal injuries from the short-

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[14] See Barbara G. Levi, Frank N. von Hippel, and William H. Daugherty, "Civilian Casualties from 'Limited' Nuclear Attacks on the U.S.S.R.," *International Security* (Winter 1987/1988), pp. 168-169.

> term, direct effects of the nuclear explosions. In the longer term, an additional 2-20 million might develop radiation-caused cancers. The variation was due to different assumptions concerning winds and casualty models. We also presented estimates of the casualties that would result from much smaller attacks on U.S. urban targets involving approximately 100 one-Mt [one-megaton] airbursts. We estimated that such attacks would kill 3-11 million people if a set of 100 strategic nuclear sites were targeted; 11-29 million people if about 100 military-industrial facilities were struck; and 25-66 million people if the 100 most populous city areas were bombed. The ranges resulted from the use of two alternative casualty models. The present article considers similar attack scenarios--but with the roles of the United States and the Soviet Union reversed. In brief, we find very similar consequences:
>
> -- A major U.S. attack on strategic nuclear facilities in the Soviet Union might kill 12-27 million people, kill or injure a total of 25-54 million people in the short term and cause 2-14 million people to suffer radiation-induced cancers in the longer term.
>
> -- A worst-case attack on Soviet urban areas with one hundred one-Mt airbursts would kill 45-77 million people and cause a total of 73-93 million to suffer lethal and non-lethal injuries.

Finally, bear in mind that these calculations concern themselves only with death and injury resulting directly from nuclear explosions. Other scientists have suggested that even a small number of warheads could disrupt the key infrastructure of a modern industrial society and lead to many more deaths from famine, cold, and disease that would have to be borne with a much depleted corps of health professionals and few surviving medical facilities. Indeed, the implications of an attack on either side are chilling:

> Despite its optimistic assumptions, the baseline scenario reveals that lack of transportation caused by the loss of

> refineries and imported petroleum would ripple through the economy, causing unprecedented damage. Even though we assumed that an agricultural industry would survive, the lost ability to transport and distribute food would cause half the survivors to die of starvation in the first two years--five times as many as would be killed by the attack itself. Though the attack would directly destroy only 8 percent of the nation's manufacturing capacity, mass starvation plus lack of vital supplies for industry would cut U.S. output in half the first year alone. And because no one would be available to rebuild devastated industries, the nation's production capacity would suffer for decades. Twenty-five years later, economic activity would still languish at 35 to 45 percent of its pre-attack level.[15]

Targeting with Smaller Forces

A much smaller inventory of nuclear warheads would still leave the United States with considerable flexibility to target various types of Soviet economic and military assets. Even with a much smaller inventory, the United States would not be restricted to retaliating by targeting Soviet cities, an action this country might be reluctant to undertake out of moral concerns and out of fear that it could invite retaliation in kind. With several hundred warheads, for example, it would be possible to target most Soviet petrochemical, electrical, metallurgical, and heavy-machinery industry; all major Soviet storage sites for ammunition, fuel, and other military supplies; all major tactical airfields; some troop concentrations; and all major Soviet transportation nodes and choke points en route to the European and Far Eastern theaters (see Tables 1, 2, and 3).

Targeting flexibility would remain even at these levels of warheads. One could continue to target some fixed nuclear sites such as bomber and submarine bases and mobile ICBM garrisons on the theory that doing so would remind both sides that they could not view their nuclear forces as invulnerable assets. Alternatively, one could eschew some or all types of nuclear counterforce targeting on the assumption that such targeting tends to drive the arms race, destabilize the nuclear balance, and promise little real limit on damage even if well executed. For example, it might be desirable to forgo targeting ICBM silos, if any remain in either side's force posture under deep reductions. One might also forgo the idea of attacking deployed mobile ICBMs, whether through barrage attack or through search-and-destroy missions. Such missions are likely to remain extremely difficult or impossible anyway.

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[15] M. Anjali Sastry, Joseph J. Romm, and Kosta Tsipis, "Can the U.S. Economy Survive a Few Nuclear Weapons?" *Technology Review* (April 1989), pp. 23-29.

A striking example of the difficulties associated with the search-and-destroy mission is the recent allied search operation for mobile missile launchers in the small country of Iraq, an operation that had only mixed results despite weeks of repeated sorties and no real opposi-

TABLE 2. TARGETS ASSOCIATED WITH SOVIET MILITARY FORCES

Target Category	Number of Sites
Airfields (Fixed-wing aircraft and helicopters)	30 to 40
Marshaling Yards	30 or more[a]
Major Supply Depots (Front level and above)	10
Command and Control Centers (Army level and above)	25 or more
Fixed Ammunition Storage Sites	20 to 30
Major Petroleum, Oil, and Lubricants Pipelines	10 to 15

SOURCE: Congressional Budget Office based on information from the U.S. Army.

NOTE: These figures are for a Soviet force of four fronts--equal to 16 to 20 armies, or approximately 90 maneuver divisions and associated air support.

a. Associated with these marshaling yards would be 8 to 10 major rail lines.

TABLE 3. TARGETS ASSOCIATED WITH SOVIET INDUSTRY

Industry	Approximate Number of Sites Responsible for First 50 Percent of Production	Approximate Number of Sites Responsible for First 75 Percent of Production
Molybdenum, Nickel, Magnesium	1	1
Titanium	1	2
Lead	2	4
Copper	5	12
Aluminum	9	17
Steel	19	36
Petroleum	35	70

SOURCE: Congressional Budget Office based on information in Frederic S. Nyland, "Exemplary Industrial Targets for Controlled Conflict," in Desmond Ball and Jeffrey Richelson, eds., *Strategic Nuclear Targeting* (Ithaca: Cornell University Press, 1986), p. 215.

tion. Nevertheless, many planners would like to preserve the option to carry out this type of operation.

In sum, it is reasonable to consider options that would make large reductions in the number of strategic warheads. It is also important to acknowledge, however, that adopting certain of these options would require fundamental changes in the Administration's views. Not incidentally, many past administrations held these same views, and in fact they continue to be well represented in the Congress today.

TARGETING THEATER NUCLEAR WEAPONS

Theater nuclear weapons include all nuclear weapons on delivery vehicles that are not strategic, or intercontinental, in range. These weapons include what are sometimes called tactical weapons, naval nuclear weapons (except for submarine-launched ballistic missiles that are intercontinental in range), and intermediate- and medium-range nuclear weapons.

Perhaps 2,000 to 2,500 sites are possible targets for theater nuclear weapons. This estimate, like the one for strategic weapons, has been compiled from various public sources. A large portion of the targets on the list are mobile--either Army units or ships. The remaining targets represent various types of fixed military facilities (see Table 4).

TABLE 4. POSSIBLE TARGETS FOR U.S. THEATER NUCLEAR WEAPONS

Target Category	Number of Sites
Tactical Airfields (Including secondary airfields)	100
Marshaling Yards, Rail Lines	50
Bridges, Other Major Choke Points	50
Major Supply, Petroleum, Oil, and Lubricants Infrastructure; Ammunition Depots	100
Theater Nuclear Weapons and Storage Sites	400
Major Command, Control, Communications, and Intelligence Facilities	50
Divisional Headquarters	250
Army Battalions	1,000
Major Surface Ships	250
Submarines	100
Major Ports	25

SOURCE: Congressional Budget Office based on Joshua M. Epstein, *Measuring Military Power* (Princeton: Princeton University Press, 1984), p. 174, and other sources.

Some of the sites that appear in Table 4 may also appear in the Single Integrated Operational Plan that would govern attacks using strategic weapons. This redundancy occurs primarily because theater weapons, theoretically at least, might be used before strategic weapons were employed. This tactic would be used largely in the hope that the conflict could be confined to its original geographical theater and not allowed to expand to an intercontinental nuclear war.

Current Views

Today, the United States has about 10,000 theater nuclear weapons, most of which might be needed if all of the targets in Table 4 were to be attacked. Although this table lists many fewer than 10,000 targets, a large number of extra warheads might be needed given the difficulties in finding and destroying mobile Army units and Navy ships.

The September 1991 Bush initiative has now changed U.S. and NATO policy considerably. Most notably, nuclear artillery and short-range missiles will not only be withdrawn from forward theaters but destroyed, and theater nuclear weapons aboard ships will not be deployed except in crisis. Total U.S. inventories of theater warheads might decline to about 7,500.

Alternative Views

Military analysts continue to debate the utility of using theater nuclear weapons to attack targets, particularly enemy Army units or Navy ships that could be reasonably close to one's own military units during war. Issues concerning the inaccuracy of weapons, radioactive contamination, and the rapid movements of friendly units all render the use of theater weapons risky.

For example, the Navy has been concerned that detonating nuclear weapons at short ranges would destroy or interfere with many of its own systems, and that a two-sided nuclear exchange at sea would work against its interests by reducing the effectiveness of high-technology radar, missiles, and naval aircraft, in which the United States excels. Basing theater nuclear weapons in foreign countries can also exacerbate political tensions, increase the danger of theft or loss, give other countries a politically convenient alibi for their own nuclear programs, and raise the chances that nuclear weapons would actually be used in a conflict. Of course, some analysts consider this latter effect desirable. If countries fear that war would escalate to the nuclear level, the argument goes, they may be more effectively deterred from initiating any type of war in the first place.

This range of opinions about theater weapons suggests that it is reasonable to consider a wide variety of options regarding such weapons, including options that eliminate all theater nuclear weapons and rely entirely on strategic weapons for nuclear deterrence. However, as in the case of strategic weapons, making deep cuts in theater nuclear weapons or eliminating them would require important changes in current views about how many and what kinds of these weapons are required to deter war.

CHAPTER III

OPTIONS FOR U.S. FORCES

A wide range of options for arms control and for U.S. nuclear forces exists. This chapter discusses several such options. The benchmark for comparing them is the Administration's current proposal for the structure of U.S. nuclear forces, together with CBO's assumption about how that proposal might be modified to be fully consistent with the Strategic Arms Reduction Talks Treaty.

CBO used a number of basic guidelines to select these options and to determine U.S. and Soviet forces for each one. These guidelines are discussed briefly below, with separate sections describing offensive and defensive systems.

GUIDELINES FOR CBO'S OFFENSIVE FORCE OPTIONS

To begin, CBO assumed that, in all of the options in this study, the two countries would maintain a parity in numbers of long-range nuclear warheads. In all likelihood, this implies that reductions in weapons systems would take place in the context of bilateral negotiations between the United States and the Soviet Union. But unilateral or bilateral reductions made without a formal treaty might also be considered. Either side may determine that by reducing forces unilaterally, it could save money without reducing military effectiveness. Indeed, some military analysts have proposed that the United States undertake unilateral reductions, believing they might induce similar Soviet actions.[1] President Bush has successfully employed such an approach for reducing theater nuclear forces, inducing even greater cuts from Soviet President Gorbachev that include reductions in both theater and strategic weaponry. President Gorbachev's 1989 unilateral conventional force reductions in Europe are another example of this approach.

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[1] Stansfield Turner, "Scrap 15,000 Warheads," *New York Times*, March 24, 1991, p. E17; Carl Kaysen, Robert S. McNamara, and George W. Rathjens, "Nuclear Weapons After the Cold War," *Foreign Affairs* (Fall 1991), pp. 107-108.

Also possible, and conceptually quite innovative, are arms control schemes that would contain much less detail on which systems should be reduced but rather would simply require each side to reduce its arsenal by a given percentage. The best way to make such reductions probably would not use warheads as the accounting unit, since different warheads can have different deterrent values, but would allow each side to weight all of its systems as it saw fit so that its total force would be worth a given number of total points. Each side could then be given the right to reduce the other side's total force by some percentage of these accounting points; the process could be iterative if desired.[2]

Finally, both sides, without formal negotiations, may refrain from deploying certain types of weapons that could be destabilizing. One example of tacit arms control is the restraint both sides have demonstrated in deploying effective antisatellite weapons.

Throughout this study, warhead counts refer to the total number of warheads that each country actually deploys or possesses, rather than any special counting systems such as those contained in the START treaty. Thus, the presumption is that each side would be left to make its own forces as effective as possible for stability and survivability, and that the arms treaty itself would not do so--except to the extent it might ban particularly dangerous types of weapons systems.[3] In regard to systems such as bombers for which the number of warheads used operationally is frequently less than the maximum load those systems are designed to carry, this study assumes that the maximum possible load would be carried.

All the options discussed in this study would maintain a triad of strategic forces (a basic description of the various weapons systems that make up the triad is offered in Appendix A). The systems are intended to enhance deterrence in a synergistic way, in the sense that a hypothetical technological breakthrough that reduced the effectiveness of one strategic system would almost certainly not affect the systems in the other two legs of the triad to the same degree. Moreover, any effort by one country to attack simultaneously all three types of systems the other country possesses, in an attempt to disarm the adversary, would create serious timing and coordination problems that an attacker probably could not surmount.

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[2] William M. Herman, "A New Practical Approach to Nuclear Arms Reductions" (Johns Hopkins University, unpublished paper, 1985).

[3] This assumption deviates from the counting rules in the START treaty, which significantly understate numbers of warheads. Although the START treaty permits 6,000 countable warheads, the actual warhead count permitted by the treaty could be several thousand higher.

In addition, each option was designed to retain a substantial percentage of the total warhead arsenal on each type of strategic system, and to maintain a large number of delivery systems, so that the triad would be robust. Indeed, the proposed options would reduce warheads by much greater percentages than they would reduce delivery systems or launchers, thereby reinforcing the durability of the triad.

To reduce the total number of warheads while still maintaining a robust triad, CBO assumed that each of the post-START options would include some missiles that carried a reduced or "downloaded" number of warheads relative to their proven maximum loading. Reducing the number of warheads on some missiles, as allowed under the START treaty, raises controversial issues concerning verification and compliance that are further addressed in Chapter VI. But it would also yield benefits, lessening the incentives for either side to attempt a first strike against the other. In particular, it would reduce the number of one country's warheads that could be destroyed by any single incoming warhead from the other side, and thereby would reduce the theoretical benefits associated with so-called counterforce attacks.

Two ways exist to download warheads. A new "bus," the last stage of a rocket that dispenses warheads individually once the main rocket engines have stopped burning, can be designed. Alternatively, some warheads can be removed from an existing bus without any design changes in the bus.

To minimize dangers associated with noncompliance or "breakout," all of the missiles that are assumed to have their warhead loadings reduced in the various options have relatively small "throwweight" or payload (always less than 2,500 kilograms). This factor limits the degree to which breakout could quickly lead to a massive increase in the number of warheads that either side could use in an attack.[4]

Downloading could reduce bomber warhead loadings as well, and some of the options assume that they would be reduced. In the case of aircraft, downloading implies changing the weapons launchers in bomb bays, or removing the equipment on the structural "hard points" of the wings that permits munitions to be carried externally.

Ideally, next-generation missiles and bombers should be designed to carry only the number of warheads with which they will be deployed. But downloading seems an acceptable approach for the current generation of systems, as discussed in Chapter VI.

GUIDELINES FOR CBO'S DEFENSIVE FORCE OPTIONS

Defenses could be used against all three legs of the triad: strategic ballistic missile defenses could intercept intercontinental ballistic missile and submarine-launched ballistic missile warheads, and air defenses could intercept long-range bombers and cruise missiles. To protect troops against theater nuclear weapons, theater defenses could include theater ballistic missile defenses and theater air defenses. Weapons with shorter ranges (theater weapons) are commonly differentiated from long-range weapons (strategic weapons) because theater weapons are incapable of crossing the oceans that separate the United States and the Soviet Union.

Strategic Missile Defenses

The Soviet Union has already deployed a small system of strategic defenses against ballistic missiles, though a major attack would easily overwhelm this system. The United States, through the Strategic Defense Initiative Organization of the Department of Defense, is currently developing a system of defenses against ballistic missiles that is intended to provide some degree of nationwide protection and eventually to have substantial capability against a major attack. The short-term plan for limited protection is called "GPALS," which means Global Protection Against Limited Strikes, and the long-term goals are described as Phase I and follow-on systems.

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[4] The definition of throwweight used throughout this study includes the weight of the post-boost vehicle (PBV) as well as the weight of any reentry vehicles, decoys, and penetration aids carried on the PBV.

Deploying the U.S. system would require renegotiating or abrogating the Anti-Ballistic Missile Treaty, and could complicate the START treaty. As recently as August 1991, during the signing of the START treaty in Moscow, several prominent Soviet officials stated that if the United States were to deploy strategic defenses, the Soviet Union would feel compelled to withdraw from the START treaty in order to deploy more missiles.[5] Thus, deployment of defenses could interfere with carrying out the treaty. Moreover, the technical feasibility of strategic defense systems remains highly debatable. Alternatively, an effective system of defenses--if properly developed--could reduce the risks associated with what may be the most serious threat to U.S. security: the threat of nuclear attack.

This study's treatment of defenses begins by acknowledging that the debate over this highly contentious topic is far from resolved. Accordingly, each option in this study has two suboptions associated with it: one that would include some type of limited defense system and another that would not.

Assumptions about the size of defensive systems range from the Administration's plan for a large-scale system of defenses to a highly limited defensive system that would comply with most provisions of the existing ABM treaty. The size of defenses under each option is roughly scaled to the size of the arsenals and to the typical warhead capacity of deployed ballistic missiles. Regardless of whether defenses are deployed or not, all options assume that basic research into strategic defense technologies would continue at roughly current levels. This research would provide a hedge against the possibility that the Soviet Union will deploy large strategic defenses of its own.

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[5] George Leopold, "With START Signed, U.S. Shifts Focus to Implementation," *Defense News* (August 5, 1991), p. 19.

Air Defenses

The Soviet Union has deployed an extensive system of air defenses intended to shoot down incoming bombers and cruise missiles. Air defenses are also intended to defend against conventional attack, making it difficult to place limitations on them. Moreover, what types of limitations would be meaningful in this context? It is difficult to discern. The most likely candidates seem to be surveillance (AWACS) aircraft and mobile surface-to-air missiles. If the United States finds itself without bombers or cruise missiles that are able to defeat Soviet air defenses, future strategic arms control may necessitate limits on these defense systems as well.

The United States also has defenses against Soviet bombers and cruise missiles, although these defenses are small relative to Soviet defenses--partly a reflection of the limited capabilities of the Soviet bomber force. Because the Administration and the Congress have made no significant efforts to change the air defense program, and because there seems to be no pressing rationale for overhauling this system, CBO assumes that the funding for air defenses continues at current levels for all options.

Theater Missile Defenses

Finally, the Administration plans to deploy defenses against theater (short-range) missiles, beginning in the mid-1990s. The Congress appears to reflect an emerging consensus that the United States should develop some form of defenses to protect U.S. troops and allies overseas against shorter-range ballistic missiles like the Scud. Thus, all the options in this study include funding at the levels the Administration proposed in its 1992-1993 budget.

THE ADMINISTRATION'S PLAN AND A VARIATION THAT COMPLIES WITH START

The Administration's current plan for U.S. nuclear forces, coupled with some assumptions about long-term choices, would chart the course for those forces between now and the year 2006--the time period examined in this study. This section examines the Administration's plan and then considers changes that might be made in that plan if the START treaty is ratified.

The Administration's Plan

The current Administration submitted its plan for U.S. nuclear forces to the Congress in February 1991, and effectively updated it on September 27, 1991, when President Bush made a major address to the nation (see Box 2). The updated plan envisions buying fewer new forces than was the case under plans the Administration presented as recently as 1990. This reduction reflects fiscal limits, the prospect of a START treaty, and the post-coup changes in the Soviet Union. Overall, the Administration's plan would reduce the level of U.S. strategic warheads from about 12,900 warheads in early 1991 to about 11,500 warheads by the year 2006, when the plan is assumed to be fully in effect (see Table 5 for details).

Despite this reduction, the plan reflects the Administration's strong commitment to nuclear forces. Secretary of Defense Cheney has said that the Soviet Union retains significant nuclear capability and is modernizing it across the board. Thus, the Secretary feels that the United States must continue an aggressive program of modernization. This stance is reflected in the Administration's plan to modernize all three legs of the U.S. triad of strategic offensive forces, while also deploying a system of defenses.

Strategic Offensive Forces. The Administration's plan, as reflected in the President's budget for fiscal years 1992 and 1993, would stop the procurement of Trident submarines at 18 boats, though it would modify (or backfit) the first eight Trident submarines to carry the larger and more accurate D5 missile (see Table 6). The D5 missiles are assumed to be deployed with a full load of Mark 5 (W-88) warheads. The recent delay in restarting the Rocky Flats plutonium processing facility has temporarily delayed the production of the W-88, possibly forcing the most recent Trident II submarine to be deployed without a full load of Mark 5 warheads. The Drell Commission's findings that accidental

BOX 2
President Bush's September 1991 Initiative and President Gorbachev's October Response

On September 27, 1991, President George Bush presented a major initiative for U.S. nuclear policy and for U.S.-Soviet arms control. This initiative is especially significant for its effects on shorter-range, or theater, nuclear weapons, but also has important implications for strategic nuclear policy It also contains arms control proposals that, if accepted by the Soviet Union, could lead to additional deep reductions. The President's proposals would affect three areas of nuclear policy: force structure, operational procedures, and arms control proposals.

Force Structure

U.S. nuclear artillery shells numbering about 1,300 and U.S. short-range nuclear ballistic missile warheads numbering about 850 will be destroyed, eliminating all U.S. weapons in these categories. To be specific, the nuclear warheads will be disassembled, with the fissile materials being placed in safe storage or used as nuclear fuel.

An as yet undetermined number of naval nuclear weapons will be destroyed--including antisubmarine depth charges, among other systems.

In total, theater arsenals apparently would decline by about 2,500 warheads, or 25 percent.

In the realm of strategic weapons, the new short-range attack missile (SRAM II) program will be canceled. According to remarks made by the Chairman of the Joint Chiefs of Staff on September 28, 1991, a related program--the tactical short-range attack missile (SRAM-T) system--will also be canceled. In addition, the Minuteman II missile, already slated for retirement, will be retired more quickly than previously planned. Finally, basing for the small intercontinental ballistic missile, or Midgetman missile, will be changed from mobile launchers to fixed silos. Otherwise, the program will not be affected.

Operational Procedures

U.S. nuclear bombers will no longer maintain constant 24-hour runway alert status. About 40 bombers were on runway alert at any given time before this decision. The alert status of the bombers could be restored within perhaps 24 hours if necessary. Remaining Minuteman II missiles will also be taken off alert status.

U.S. naval nuclear weapons, excepting those deployed on long-range ballistic missiles, will be withdrawn from forward deployment in peacetime and stockpiled in the United States. This policy will pertain to weapons deployed on attack submarines, surface ships, aircraft based on aircraft carriers, and land-based naval aircraft.

Arms Control Proposals

The President has encouraged, and received, reciprocating Soviet pledges regarding short-range weapons. In addition, President Bush has called for negotiations to eliminate land-based missiles with multiple warheads. The Soviet Union has many more missiles of this type than the United States, but the President hopes that the changing Soviet political environment will nevertheless make this proposal attractive to leaders in the Kremlin. Under this proposal, intended to be in accord with agreements reached in the Strategic Arms Reduction Talks (START) negotiations, missiles carrying many warheads would have to be destroyed. Missiles with the capacity to carry only a few warheads could, alternatively, be retained provided that they were deployed with only one warhead each.

Soviet Response

On October 5, only eight days after President Bush's speech, Soviet President Gorbachev made a response to the U.S. initiative that was well received in Washington. Responding to the Bush initiative, President Gorbachev announced that the Soviet Union, too, would destroy its nuclear artillery shells and warheads from its nuclear surface-to-surface missiles. He also matched U.S. actions in deciding formally to take Soviet strategic bombers off alert (even though these bombers never were on alert in the same way that U.S. bombers were), and to take off alert 503 long-range missiles. He also confined mobile missiles to their garrisons during peacetime conditions. Furthermore, Gorbachev canceled several weapons programs, including an air-delivered missile, a new small road-mobile ICBM, and modernization of the rail-mobile SS-24 missile. In addition, he suggested that the Soviet Union might prove flexible on the subject of limited missile defenses.

Going beyond President Bush, Mr. Gorbachev proposed that the United States and the Soviet Union agree to destroy all naval nuclear weapons, except for long-range ballistic missile warheads, and that they further agree to withdraw all air-deliverable theater nuclear weapons to their own territories. In addition, he announced that, after the seven-year implementation period for the START treaty, the Soviet Union would make further reductions in strategic arms, apparently acting as if START limited countable strategic warheads to 5,000 rather than the 6,000 limit that actually appears in the treaty. He called on the United States to join the Soviet Union in pledging never to be the first country to use nuclear weapons in a war. Finally, the Soviet president suggested that the two countries negotiate even deeper cuts in strategic weapons, and that they--perhaps in cooperation with the other nuclear powers--pursue an end to nuclear testing.

The two leaders also made other proposals to improve the safety of nuclear weapons and simplify nuclear command structures.

TABLE 5. U.S. FORCE POSTURES AND THEIR MAIN CHARACTERISTICS IN 2006

	Warheads		Deployed
Plan or Option	Strategic	Theater	Strategic Defenses[a]
Forces as of Early 1991	12,900	10,000	None
	Administration's Plan and Variation		
Administration's Current Plan[b]	11,500	7,500	GPALS, Phase I[c]
Administration's Plan with START[d]	10,500	7,500	GPALS, Phase I[c]
	Post-START Options		
I. Ban Heavy ICBMs, Limit Defenses	10,500	7,500	GPALS
II. Reduce Strategic Warheads to 6,000	6,000	4,000	GPALS, no space defense
III. Reduce Strategic Warheads to 3,000	3,000	2,000	One-half GPALS, no space defense[e]
IV. Reduce Strategic Warheads to 1,000	1,000	0	One-eighth GPALS, no space defense[e]

SOURCE: Congressional Budget Office.

NOTES: GPALS = Global Protection Against Limited Strikes; ICBMs = intercontinental ballistic missiles; Phase I = first stage of a large defense system against a ballistic missile attack; no space defense = space-based interceptors cannot be deployed.

a. All plans and options include the Administration's program for the Tactical Missile Defense Initiative (TMDI). The references to GPALS in the table are to the strategic components of the program, not to TMDI.

b. An amalgamation of formal Department of Defense plans for the next six years and CBO projections of what the Administration's plans are likely to include after that date.

c. The Administration has not recently reaffirmed its commitment to Phase I, but neither has it disavowed its intention to deploy large defenses.

d. CBO's estimate of how the Administration's plan might be modified in order to comply with START treaty limitations that seem likely to enter into force as of this writing (October 1991).

e. "One-half GPALS" and "one-eighth GPALS" imply reductions of about 50 percent and 85 percent in the number of interceptor missiles per base.

explosions in the third stage of the missile might cause plutonium leaks could delay production further if the Congress decides to require the Navy to correct the problem. By the year 2006, however, these problems are assumed to be corrected and all D5 missiles are assumed to carry only Mark 5 warheads.

Seventy-five B-2 bombers are deployed, consistent with the Administration's policy stated in the Major Aircraft Review. As stated in the fiscal year 1992-1993 budget, however, the B-52 fleet would be reduced to 95 B-52H bombers, all configured to carry cruise missiles.

For land-based ballistic missiles, the United States is assumed to keep the MX missile in silos and to deploy 500 single-warhead small intercontinental ballistic missiles (SICBMs) in silos.[6] The Minuteman force is reduced to 500 Minuteman IIIs as the older Minuteman II missiles are retired.

Defensive Systems. The Administration's budget includes substantial funding increases in the Strategic Defense Initiative program, in part to accommodate the new accidental launch protection system, Global Protection Against Limited Strikes. GPALS deployment would begin in the late 1990s. The Administration would also fund the development of Phase I of a larger system of defenses. The planned level of defenses is described in Table 7.

As currently on the drawing boards, GPALS would consist of 1,000 space-based interceptors (known as brilliant pebbles), 60 space-based sensors (brilliant eyes), 750 ground-based interceptors based at six sites, and six ground-based radar systems. GPALS would also include a system of theater defenses--to be deployed starting in the mid-1990s--to protect U.S. troops and allies overseas from short-range ballistic missiles.

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[6] CBO assumes MX production does not extend beyond the 114 missiles already authorized through fiscal year 1991. The Administration takes this approach in its budget for fiscal years 1992 and 1993, although this issue remains contentious in the Congress. See "MX Backing," *Aerospace Daily*, April 8, 1991, p. 43.

TABLE 6. U.S. STRATEGIC OFFENSIVE FORCES UNDER ALTERNATIVE FORCE POSTURES

	MX		MM		Trident Submarines[a]	
Plan or Option	Rail	Silo	III	SICBM	D5	C4
Forces as of Early 1991[b]	0	50 (10)	500 (3)	0 (1)	3 (8)	8 (8)
Administration's Plan and Variation						
Administration's Current Plan[c]	0	50	500	500	18	0
Administration's Plan with START[d]	0	50	316/35[e] (1/3)	500	18	0
Post-START Options						
I. Ban Heavy ICBMs, Limit Defenses	0	50	316/35[e] (1/3)	500	18	0
II. Reduce Strategic Warheads to 6,000	0	50	86 (1)	200	10	8
III. Reduce Strategic Warheads to 3,000	0	0	208 (3)	0	10 (3)	8 (3)
IV. Reduce Strategic Warheads to 1,000	0	0	200 (1)	0	10 (1)	8 (1)

SOURCE: Congressional Budget Office based on Department of Defense data.

NOTES: The numbers in parentheses indicate the number of warheads on each launcher. Unless otherwise indicated, the number of warheads per launcher remains constant as one descends in any single column. For the Minuteman III, under the Administration's plan with START and Option I, 316 missiles are deployed with one warhead each and 35 are deployed with three warheads each.

The Soviet Union is assumed to make corresponding reductions (see Appendix D).

ICBMs = intercontinental ballistic missiles; MM III = Minuteman III missile; SICBM = small ICBM, also called the Midgetman, assumed to be deployed in silos.

[a] Each submarine carries 24 missiles.

(Continued)

Phase I would use the same systems but deploy more than 4,000 brilliant pebbles, roughly 260 brilliant eyes, 2,000 ground-based interceptors, and an unspecified number of ground-based radar systems. If they perform as advertised, GPALS could intercept roughly 100 to 200 warheads and Phase I could intercept at least 1,500 warheads.

Phase I would be the first step in a system of defenses designed to defend the United States against a large-scale nuclear attack involv-

TABLE 6. Continued

	B-2	B-1	B-52	Deployed Launchers	Deployed Warheads	Throw-weight (10^6 kg)
Forces as of Early 1991[b]	0 (18)	97 (24)	95 (20)	1,885	12,850	2.0
			Administration's Plan and Variation			
Administration's Current Plan[c]	75	97	95	1,749	11,534	2.1
Administration's Plan with START[d]	75	97	95	1,600	10,455[f]	1.9
			Post-START Options			
I. Ban Heavy ICBMs, Limit Defenses	75	97	95	1,600	10,455[f]	1.9
II. Reduce Strategic Warheads to 6,000	33	97 (12)	0	898	6,000	1.2
III. Reduce Strategic Warheads to 3,000	0	90	0	730	3,000	1.1
IV. Reduce Strategic Warheads to 1,000	0	90 (4)	0	722	992	1.0

b. Other systems not shown: 450 Minuteman II, 12 Poseidon submarines with 16 C4 missiles each, 10 Poseidon submarines with 16 C3 missiles each, and 77 B-52G bombers. The Minuteman II, C4, and C3 missiles each carry 1, 8, and 10 warheads, respectively. The B-52G bombers each carry 12 warheads.

c. Amalgamation of formal Department of Defense plans for the next six years and CBO projections of what the Administration's plans are likely to include after that date.

d. CBO's estimate of how the Administration's plan might be modified in order to comply with START treaty limitations that seem likely to enter into force as of this writing (October 1991).

e. It is assumed under START and Option I that the United States is allowed to reduce warhead loadings on the Minuteman III, and reduces the warheads on 316 of them.

f. The number of START-countable warheads is 5,999 for this START force and Option I.

ing thousands of warheads. Several Administration officials, including the Chairman of the Joint Chiefs of Staff (JCS), Colin Powell, have stated recently that deploying a Phase I defense remains a JCS requirement.[7]

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[7] See "Gen. Powell Says Time is Ripe for Short-Range Nuclear Weapons Ban," *Aerospace Daily*, September 30, 1991, pp. 507-508; and "Washington Roundup: SDI vs SDI," *Aviation Week & Space Technology* (February 25, 1991), p. 19.

Theater Offensive Forces. Although discussions of arms control often exclude theater nuclear weapons, they are an important part of nuclear forces. Today, the U.S. arsenal of shorter-range forces holds roughly 10,000 warheads (see Table 8). Hence, these weapons are about as numerous as their longer-range cousins, though they are expected to decline in number by about 25 percent as a result of the President's September initiative. CBO's assumptions about U.S. theater forces under the Administration's current plan are shown in Table 8 as well.

TABLE 7. U.S. DEFENSIVE SYSTEMS UNDER ALTERNATIVE FORCE POSTURES

Plan or Option	Type of Defense	Number of Interceptors		Space-Based Sensors[b]	Pursue Phase I?
		Space-Based	Ground-Based[a]		
Administration's Plan and Variation					
Administration's Current Plan	Large-Scale[c]	More Than 4,000	2,000	260	Yes
Administration's Plan with START	Large-Scale[c]	More Than 4,000	2,000	260	Yes
Post-START Options					
I. Ban Heavy ICBMs, Limit Defenses	Limited	1,000	750	60	No
II. Reduce Strategic Warheads to 6,000	Limited	0	750	40 to 50	No
III. Reduce Strategic Warheads to 3,000	Limited	0	400	30 to 40	No
IV. Reduce Strategic Warheads to 1,000	Limited	0	100	30 to 40	No

SOURCE: Congressional Budget Office based on Department of Defense data.

NOTE: ICBMs = intercontinental ballistic missiles; Phase I = first stage of a large defense system against a ballistic missile attack.

a. Ground-based interceptors to be deployed at six sites.

b. If concerns about space-based sensors emerge, ground-based suborbital sensors launched during an attack could be substituted in Options I through IV. These sensors could be similar to the ground-based surveillance and tracking system (GSTS) proposed by the Strategic Defense Initiative Organization.

c. The Administration's current plan and the Administration's plan with START also deploy the Global Protection Against Limited Strikes system before deploying a large-scale defense.

Administration's Plan with START

Because the Administration's current plan would maintain more launchers and more warheads than the treaty would permit, this plan would not be fully consistent with the recently signed START treaty. After a review of the detailed provisions of the START treaty, this section offers one way in which the Administration's plan might be modified to accommodate those provisions.

START Treaty Provisions. Presidents Bush and Gorbachev signed the START treaty in August 1991. Although some of the details of the treaty are still classified, most of the major elements have been released to the public. Box 3 shows the details of the START treaty that are known to date. If ratified, the START treaty would limit the United States and the Soviet Union to 6,000 START-countable warheads each, only 4,900 of which could be based on ballistic missiles and only 1,100 of which could be based on mobile ICBMs.

The treaty would also limit both sides to 154 "heavy" ICBMs that can carry large payloads and therefore large numbers of warheads. Given this limit, the Soviet Union would be required to cut its force of 308 SS-18 missiles in half; the United States would be unaffected, because it no longer deploys any heavy ICBMs. The purpose of the limit on heavy missiles is to reduce the possibility that these missiles could be modified to carry many more warheads than they carry today.

The START treaty would also limit each side to 1,600 launchers--the ballistic missiles and bombers that carry nuclear warheads. START reductions would be carried out in three phases over a total of seven years. The treaty would remain in effect 15 years after signing, with five-year extensions possible by mutual agreement. For the purposes of this study, the START treaty is assumed to be ratified by late 1991 and to enter into force in early 1992, making early 1999 the deadline for fully compliant forces.

START would be the first treaty to count warheads on ballistic missiles solely by declaration. Under START rules, each side must de-

TABLE 8. U.S. THEATER OFFENSIVE SYSTEMS UNDER ALTERNATIVE FORCE POSTURES (In thousands of warheads)

Plan or Option	Artillery Shells	Tactical Short-Range Attack Missiles	Bombs on Air Force Tactical Aircraft	Bombs on Carrier-Based Aircraft
Forces as of Early 1991	2.0	0	2.0	1.5
Administration's Plan and Variation				
Administration's Current Plan	0	0	2.0	1.5
Administration's Plan with START	0	0	2.0	1.5
Post-START Options				
I. Ban Heavy ICBMs, Limit Defenses	0	0	2.0	1.5
II. Reduce Strategic Warheads to 6,000	0	0	1.0	1.0
III. Reduce Strategic Warheads to 3,000	0	0	0.8	0
IV. Reduce Strategic Warheads to 1,000	0	0	0	0

(Continued)

SOURCE: Congressional Budget Office based on data from Theodore B. Taylor, "Warhead Dismantlement and Fissile-Material Disposal," in Frank N. von Hippel and Roald Z. Sagdeev, *Reversing the Arms Race* (New York: Gordon and Breach, 1990), p. 93.

clare the actual number of warheads on each type of missile it deploys; in some cases, that number may be lower than the maximum number with which it was flight-tested.

This precedent was established at the December 1987 Washington Summit between Presidents Reagan and Gorbachev. During this meeting, the two presidents declared warhead loadings for each deployed missile type. Most missiles were declared to carry their flight-

TABLE 8. Continued

Plan or Option	Anti-submarine Bombs	Sea-Launched Cruise Missiles	Total Theater Warheads[a]	Total All Warheads[b]
Forces as of Early 1991	1.8	0.4	10.0	22.9
Administration's Plan and Variation				
Administration's Current Plan	1.0	0.4	7.5	19.0
Administration's Plan with START	1.0	0.4	7.5	18.0
Post-START Options				
I. Ban Heavy ICBMs, Limit Defenses	1.0	0.4	7.5	18.0
II. Reduce Strategic Warheads to 6,000	1.0	0.4	4.0	10.0
III. Reduce Strategic Warheads to 3,000	0.6	0	2.0	5.0
IV. Reduce Strategic Warheads to 1,000	0	0	0	1.0

NOTE: ICBMs = intercontinental ballistic missiles.

a. Includes spares and stockpiled weapons.

b. Includes deployed strategic warheads (see Table 6).

tested maximum with two notable exceptions: the Soviet SS-N-23 SLBM was declared to carry 4 warheads rather than its extensively tested maximum of 10 warheads, and the U.S. Trident II missile (D5) was declared to carry 8 warheads rather than its tested maximum of 10 and its designed maximum of 12. During the summit, the two Presidents agreed that procedures would be established in the treaty to monitor compliance with these declared loadings.

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BOX 3
Provisions of the START Treaty

Warheads

6,000 START-countable warheads of which
- 4,900 can be on ballistic missiles
- 1,540 can be on heavy ICBMs (SS-18)
- 1,100 can be on mobile ICBMs

Launchers

1,600 total launchers (ballistic missiles and bombers) of which 154 can be heavy ICBMs (SS-18)

Throwweight

Sum of ballistic missile payloads limited to 3,600 metric tons

Counting Rules

ALCM bombers:[1]

Warheads: United States: 10 warheads/bomber for the first 150 bombers. Actual maximum load for each additional bomber. No bomber can carry more than 20 long-range ALCMs.

Soviet Union: 8 warheads/bomber for the first 180 bombers. Actual maximum load for each additional bomber. No bomber can carry more than 16 long-range ALCMs.

Launchers: Each ALCM bomber counted as one launcher for both sides.

Penetrating bombers: Each non-ALCM bomber counted as one warhead and one launcher.

Ballistic missiles:

Warheads: Determined by declaration for each type made at December 1987 Washington Summit.
Launchers: Each missile counted as one launcher.

Treaty Duration

Fifteen years from signing unless superseded. Can be extended for five-year increments if both sides agree.

Verification and Monitoring

Data base exchanges and many types of on-site inspection. Telemetry encryption forbidden during missile-test flights.

Politically Binding Agreements

Each side limited to 880 sea-launched cruise missiles with ranges greater than 600 km. Soviet Union limited to 500 medium-range Backfire bombers and has agreed to adopt operational measures to make it difficult for bombers to reach the United States.

Strategic Defenses

Not explicitly limited by START treaty.
(Soviet Union has threatened to exceed treaty limits if the United States deploys defenses in violation of the ABM treaty.)

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[1] ALCM bombers carry long-range, air-launched cruise missiles with ranges exceeding 600 km.

Information made public about the START treaty indicates that more types of missiles, including the Soviet SS-N-18 and the U.S. Minuteman III missiles, may be deployed with warhead counts below their flight-tested maximums. Although the provisions in the START treaty are complex, two basic rules govern downloading. First, the total number of warheads removed from the missiles on each side, and thereby exempted from counting toward the warhead limits, cannot exceed 1,250. However, the 1,250 limit does not apply to the Soviet SS-N-23 missile or the U.S. D5 missile, as long as they are deployed in the configurations declared at the 1987 Washington Summit. Furthermore, this 1,250 limit only applies if the SS-N-18 or the Minuteman III is deployed, because the total number of warheads removed on up to two other types of ballistic missiles cannot exceed 500.

Second, existing types of missiles (except the SS-18) can be downloaded by up to four warheads per missile. However, if more than two warheads are removed, the post-boost vehicle (or bus) that carries the warheads must be destroyed and must be replaced by a new bus designed for fewer warheads. The only exceptions to this rule are the SS-N-18 and the Minuteman III; each must have its current bus destroyed if any warheads are downloaded. These provisions reflect concerns that the large numbers of downloaded missiles could increase the potential military significance of breakout.

The START treaty would also break ground by introducing wide-ranging provisions for verification that would be even more intrusive than those currently in force as part of the Intermediate-Range Nuclear Forces Treaty, including short-notice inspections at sites where violations are suspected.

The START treaty would not limit shorter-range nuclear systems; however, in a separate politically binding agreement, sea-launched cruise missiles will be limited to 880 per side. An additional agreement will limit the number of Soviet medium-range Backfire bombers to 500 and will constrain them operationally in such a way as to make their use against the United States difficult, presumably by limiting their in-flight refueling capability.

Accommodating START. The Administration could, of course, further reduce its program of modernization to accommodate the number of launchers and warheads the treaty permits. However, in light of the Administration's emphasis on continuing modernization, retiring older systems is more likely. Defense systems might also undergo changes (see Table 5 and Table 7, which summarize the changes).

Specifically, this study assumes that, to comply with the START limits on the number of launchers and warheads, the Administration would eliminate 149 Minuteman III missiles and would reduce the number of warheads on 316 of the remaining 351 missiles from three warheads to one warhead (see Table 6). This downloading would probably not occur until the years 2003 to 2005, when the SICBM would be deployed. The Soviet Union would also have to make changes. It would have to cut its force of large SS-18 missiles in half, from 308 to 154 missiles, to comply with the START limit on heavy ICBMs. It is also assumed to eliminate some land-based missiles (the final 200 six-RV SS-19 ICBMs) and submarines (including eight Delta III ballistic missile submarines) (see Appendix D). Apparently, the Soviet Union would reduce its warheads even further than projected here, given President Gorbachev's October pledge to cut strategic warheads by another 1,000 after the seven-year START implementation period. Details of this pledge are not yet clear, however, so CBO has not revised its projections for Soviet forces.

Because the Administration places a high priority on defenses, this option assumes that both GPALS and Phase I would be deployed. Although deploying missile defenses would apparently be consistent with the letter of the START treaty, it would not be consistent with the ABM treaty. Indeed, the Soviet Union has expressed strong opposition to U.S. strategic defense deployments and has indicated that it might expand the number of its strategic warheads above START limits if the United States violates the ABM treaty. If the United States decides not to deploy defenses, the cost of the Administration's plan under START would be reduced somewhat (see Chapter IV).

With the exception of sea-launched cruise missiles with nuclear warheads, the START process did not deal with shorter-range nuclear systems. Since the Administration apparently plans to procure no more sea-launched cruise missiles, START would not constrain its plan for these weapons. The Administration's plan for all other shorter-range weapons is assumed to remain unaltered by START but to be consistent with the President's September 1991 initiative on nuclear forces.

POST-START OPTIONS

Over the next few years, the United States and the Soviet Union may go beyond the START treaty and negotiate an agreement imposing more dramatic limits on nuclear weapons. Some military analysts and policymakers including former Secretary of Defense Harold Brown, Presidents Reagan and Gorbachev at the 1986 Reykjavik Summit, and now President Bush have urged just such a course.

This section identifies four options that illustrate possible U.S. forces in a post-START world. The options define U.S. forces through the year 2006. Obviously, no one can predict the exact nature of a post-START treaty or the forces that would be consistent with such a treaty. The intent of this section is to present illustrative options that suggest the range of potential outcomes.

Although they are illustrative, the options take into account the weapons systems that are now in development. Moreover, the options reflect the preferences the United States has historically displayed. For example, since the early 1960s, the United States has demonstrated a strong preference for basing large portions of its arsenal on ballistic missile submarines and long-range bombers, and recent U.S. developments such as the accurate D5 submarine-launched ballistic missile and the B-2 penetrating bomber reflect this preference. Based on these historical trends, one would expect the United States to continue basing a large portion of its arsenal on these two legs under any future arms control limitations. Illustrative Soviet forces for each option can also be constructed using the same techniques. These forces are shown in Appendix D.

Option I: Ban Heavy Missiles and Limit Defenses

Of the post-START options considered in this study, Option I assumes the most modest changes. Under Option I, the total number of U.S. warheads would remain at START levels as assumed in the Administration's START plan (see Table 5). The only significant difference between the forces in this option and those in the Administration's plan that complies with START is that, in this option, limits on missile defenses are coupled with a ban on heavy intercontinental ballistic missiles. The ban on heavy missiles would only affect the Soviet Union, since the United States has no heavy ICBMs. The ban would reduce the total payload or throwweight of Soviet missiles and so reduce the risk that the Soviet Union could cheat by breaking out of an arms limitation treaty and adding warheads to its large missiles. This option would be in accord with President Bush's September call for negotiations focusing on land-based missiles with multiple warheads. But it would not eliminate all such weapons because of the heavy reliance placed on them by the Soviet Union.

Strategic Offensive Forces. Specifically, under this option the Soviet Union would be required to eliminate its remaining large land-based missiles (154 SS-18 ICBMs). CBO assumed here that the Soviet Union would compensate for the loss of the SS-18s by deploying 154 more SS-24s, a missile that can carry 10 warheads but has less than half the capacity (throwweight) of the SS-18. Although this option does not reduce the number of warheads per missile, it does reduce Soviet throwweight by roughly 20 percent over START levels and by 54 percent over possible levels without START.

Defensive Systems. Since the Soviet Union would be unlikely to give up its most capable missile without some concessions by the United States, Option I assumes that the United States would accept a ban on deploying large-scale strategic defenses in exchange for the ban on heavy ICBMs. This option assumes that if defenses were deployed, only limited defenses like GPALS would be allowed and that the United States would deploy such a system. Limited defenses are assumed to be acceptable provided that they are capable of intercepting only a few hundred warheads and provided that these limited capabilities can be adequately verified. Such a limited system might be acceptable to the Soviet Union because, at START warhead levels, it would not undermine the Soviet Union's ability to achieve an acceptable level of nuclear deterrence by retaining the ability to destroy U.S. assets even after a U.S. first-strike attack on the Soviet Union.

Specific limits on missile defenses could take many forms. Interceptors designed to destroy enemy missiles might be permitted to be deployed both on the ground and in space, as the Administration would prefer. But interceptors could be subject to numerical limits to ensure that the system would not have the capability to destroy more than a few hundred incoming missiles. These numerical limits might, for example, dictate that no more than 1,000 ground-based interceptors could be deployed at six sites in each country. Furthermore, interceptors might not be permitted to have multiple independently targeted warheads. Ground-based interceptors and radar systems would also have limited mobility to ensure they were used only for an accidental launch system and not a more capable defense. In addition, deploying new types of defenses such as directed-energy or laser weapons might be strictly limited.

Theater Offensive Forces. As in the Administration's START option, Option I would make no change in theater systems. Nuclear sea-launched cruise missiles would be limited to 880 on each side and Soviet Backfire bombers limited to 500, but all other theater systems would be unlimited. They are assumed to remain at current levels.

Option II: Reduce Strategic Warheads to 6,000

Although Option I assumes a post-START treaty that would make only modest changes in United States and Soviet forces, Option II incorporates more far-reaching changes. This option assumes a limit of 6,000 on the actual number of strategic nuclear warheads each side could deploy. The START treaty would limit each side to 6,000 warheads, but, because of special counting rules noted earlier, the treaty would permit the United States to maintain more warheads, perhaps as many as 9,000 to 11,000. Thus, this option would reduce actual U.S. warheads by at least one-third beyond START limits, close to the original cuts Presidents Reagan and Gorbachev proposed at the Reykjavik

Summit. It may be similar to the approach envisioned by President Gorbachev in his call for deeper cuts in strategic systems and negotiated reductions in shorter-range systems.

Strategic Offensive Forces. Under this approach, the United States would deploy many of the same new systems as in Option I, but in smaller numbers: the number of small ICBMs deployed in silos would be kept to 200 rather than 500, and the B-2 fleet would be kept to 33 bombers (two squadrons) rather than the 75 that the Administration proposed. The smaller B-2 fleet reflects an effort to save money, which is assumed to be a central reason for arms control beyond START. In addition, the B-52 fleet would be retired and the Minuteman III force reduced to 86 missiles, each carrying one warhead. Also, for this option and Options III and IV, the first eight Ohio-class submarines are assumed not to be backfitted with D5 missiles, and fewer D5 missiles are assumed to be purchased.

Despite these changes, this force still embodies a commitment to the strategic triad and the insurance against technical breakthroughs that the triad provides. Under this option, the United States would retain 130 bombers, 18 Trident submarines, and more than 330 ICBMs.

Defensive Systems. Because of the lower limit on numbers of warheads, if defenses were allowed, the limits on defenses would be stricter for this option. In particular, this option would prohibit all space-based defenses, though sensor systems designed to detect enemy warheads could be deployed in space. The number of ground-based missile interceptors would be limited to roughly 1,000 at six sites, as in Option I, to be certain that the defense was capable of intercepting no more than perhaps 100 warheads. Nevertheless, this defense would clearly exceed the limits of the ABM treaty.

Theater Offensive Forces. The number of theater warheads is assumed to be reduced under this option from about 7,500 to 4,000. Although this option assumes limits on shorter-range offensive systems, they are not banned entirely. Many analysts in both the United States and Europe believe that some form of European-based nuclear deterrent is still needed to demonstrate continued U.S. commitment to the region, at least in the short run. The INF treaty, which eliminated all ballistic and ground-launched cruise missiles in Europe with ranges between 500 and 5,500 kilometers, precludes the use of ballistic missiles for this purpose. Consequently, the only remaining European-based option is nuclear weapons delivered by aircraft that have the range to hit tactical targets near the Soviet Union if Soviet troops were to invade Europe.

Option III: Reduce Strategic Warheads to 3,000

Option III would limit the United States and the Soviet Union to nuclear forces consisting of no more than 3,000 strategic warheads, at least a two-thirds reduction from the U.S. level likely under the START treaty (see Table 5 on page 36). Such an agreement would also reduce by one-half the 6,000 countable warheads that would be permitted under the START treaty. This additional halving of forces might represent an easily expressed and politically attractive goal for the post-START process.

Strategic Offensive Forces. Under this option, the U.S. land-based missile force would also change. The 10-warhead MX missile would be eliminated to increase the number of intercontinental ballistic missiles that could be deployed under the tight warhead limits of this option. The small ICBM missile would be canceled, or at least deferred beyond the time frame of this study. More Minuteman III missiles would be deployed than in the 6,000-warhead option (208 versus 86).

Rather than reduce numbers of submarines, this option assumes that, to comply with lower limits on warheads, the Soviet Union and the United States agree to limit to three the maximum number of warheads that each submarine-launched ballistic missile can carry. Today, the United States has eight warheads on its newest submarine-launched missiles. This downloading of warheads would permit the United States to reduce its number of warheads while still deploying 18 submarines, the same number as under the Administration's plan. Both the United States and the Soviet Union would probably prefer to maintain a submarine fleet of substantial size because these ships have a high probability of surviving an initial enemy attack and so provide effective nuclear deterrence.

As noted earlier, reducing the number of warheads on missiles that have been designed and tested to carry a larger number of warheads does increase the risk that, in the event of a crisis, the Soviet Union (or, from the Soviet Union's perspective, the United States) could break out from the treaty and rapidly increase its inventory of deployed warheads. The threat of a substantial breakout by the Soviet Union is limited in the case of SLBMs by the relatively small payload or throwweight of its submarine-based missiles; they cannot be loaded with a large number of powerful warheads.

As an alternative to downloading, the United States could reduce the number of missiles carried on each submarine by eliminating some missile tubes, sometimes called "detubing." This approach would take longer and would cost more than downloading, but detubing would lessen the risk of breakout while still garnering the benefits of fewer warheads and a substantial submarine fleet.

In addition to reducing the number of warheads on submarine-based missiles, this option assumes that the United States forgoes deploying the B-2 bomber as part of its nuclear force posture, although it is conceivable that the 15 bombers already authorized by the Congress could be deployed in a conventional role. The B-1 bomber fleet is assumed to be reconfigured into a force designed to "shoot-penetrate." Thus, B-1 bombers would first shoot cruise missiles (unmanned, long-range missiles) from outside Soviet airspace and would then penetrate Soviet airspace to deliver shorter-range weapons.

In such a shoot-penetrate role, B-1 bombers would carry four advanced cruise missiles and eight of the shorter-range SRAM missiles or bombs. All B-52 bombers are assumed to be retired or converted to conventional bombers. Because B-2s or B-52s in conventional roles could be reconfigured to carry nuclear weapons, verifying these converted bombers could present some problems. The United States and the Soviet Union addressed this problem in the SALT II treaty by agreeing that converted bombers must have "functionally related observable differences," or FRODs, which could consist of the lack of bomb bay doors or wings without pylons that carry cruise missiles. The on-site inspection provisions of a post-START treaty would strengthen FRODs as compliance measures.

However, two factors in the 1990s may complicate the FROD solution to the verification problem: first, the FRODs may be difficult to incorporate in the B-2 because the bomber is designed to carry its payload internally and because any changes to the bomber's smooth skin could adversely affect its stealth capabilities; second, the U.S. Air Force's use of a few conventionally tipped ALCMs in the Persian Gulf War and the general success of standoff munitions during that war may foreshadow increased emphasis on long-range conventional munitions. If bombers loaded with conventional cruise missiles would be indistinguishable from bombers loaded with nuclear cruise missiles, arms control verification would be more complicated.[8] Because bombers are not well-suited to disarming first-strike attacks, however, these risks may be deemed acceptable.

Defensive Systems. As in Option II, this option would forbid deploying interceptors based in space. But Option III would impose lower limits than the preceding option on the number of ground-based missile interceptors. If defenses were allowed, Option III would allow only 400 ground-based missile interceptors, which could be deployed at several sites in each country (see Table 7). The Soviet Union is likely to insist on a lower limit on interceptors to match the reduction in the number of offensive warheads.

Theater Offensive Forces. For this option, further changes would be made in theater systems to achieve an overall goal of having all U.S. and Soviet tactical and theater nuclear weapons located in the United States and the Soviet Union during peacetime, away from zones of confrontation such as Europe or Korea. During periods of serious crisis, these weapons could be deployed to forward areas quickly to provide deterrence. In particular, all air-delivered munitions would be kept in the United States.

In addition, in Option III, nuclear SLCMs and nuclear bombs carried by carrier-based aircraft would be eliminated to improve safety and stability. Nuclear weapons carried by Air Force tactical aircraft and Navy P-3 aircraft would continue to exist, since these weapons could rapidly be deployed to Europe, Korea, or elsewhere from U.S. bases if a crisis arose. This option for theater nuclear weapons appears broadly consistent with Gorbachev's October proposal.

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[8] On the usefulness of conventional air-launched cruise missiles, see "Conventional ALCMs, Black LRCSW/MSOW Replacement Strike Iraq," *Aerospace Daily*, February 6, 1991, p. 207.

Option IV: Reduce Strategic Warheads to 1,000

Option IV assumes that a post-START agreement would limit total strategic warheads on each side to 1,000 (see Table 5). Several prominent military analysts have proposed forces of this magnitude. These proponents of a small nuclear force argue that the awesome destructive power of nuclear weapons and the latent threat of societal destruction that even a few warheads pose make large arsenals superfluous and dangerous. (Indeed, some analysts have advocated even smaller forces for these reasons.) A more rational force, according to their view, would be quite small, have very few warheads per missile, and be based on delivery platforms that have a high probability of surviving an enemy attack.

Option IV embodies the essence of these proposals. As in other options, many missiles in the U.S. arsenal are assumed to be based on submarines, which are quite likely to survive an enemy attack. Each missile in the U.S. arsenal is assumed to have only one warhead, which means that an equally armed attacker must use one or more missiles to destroy a warhead and so would gain no advantage from a first-strike attack.

Strategic Offensive Systems. Specifically, Option IV assumes that the ICBM element of the triad consists only of Minuteman III missiles carrying one warhead each. The United States is assumed to maintain 18 Trident submarines, but each missile would carry only one warhead. The B-1B bomber in this option is assumed to be reconfigured to fire cruise missiles outside Soviet territory. Cruise missiles have less capability to attack both extremely hard nuclear systems and mobile nuclear systems, so this reconfiguration would represent a move away from a counterforce strategy that focuses on destroying Soviet nuclear assets.

Although some counterforce capability would still exist on the submarine-launched D5 missiles and advanced cruise missiles, effective counterforce strikes would be difficult under this option. Most of the platforms deployed by both sides would be mobile, which would make them difficult to attack except through a barrage attack that attempted to destroy mobile platforms by saturating an area with nuclear warheads (see Chapter V). Under this option, however, neither side would have enough warheads to carry out an effective barrage attack.

Defensive Systems. If defenses were allowed under this option, all space-based defenses would be forbidden, and any ground-based systems would be limited to a small number of interceptors--perhaps 100 interceptors at no more than six sites. This option is the only one in this study that would come close to complying with the ABM treaty: it would have the proper number of interceptors, but would exceed treaty limits for the number of interceptor sites, the number of radar systems, and the defended area. The United States is assumed to deploy such a system, which would be able to defeat perhaps only a few incoming nuclear warheads (see Appendix C).

In a world of 1,000-warhead arsenals where ballistic missiles carried a single warhead, a limited protection system might only have to intercept several warheads from an accidental or unauthorized launch from a submarine. A protection system that was much more capable could seriously affect the strategic balance because of the small size of the arsenals.

Theater Offensive Forces. In this small force, all theater nuclear weapons are assumed to be banned. Thus, this option limits total nuclear warheads to 1,000. Theater nuclear weapons are eliminated for several reasons: first, even a small number of these weapons could affect the strategic balance; second, eliminating all of them would simplify verification by reducing the number of systems that have to be counted; third, eliminating them would further segregate nuclear weapons from other U.S. military forces and thereby relegate nuclear weapons to a less important role in U.S. military policy. However, by banning theater nuclear weapons, this option would not address the concerns of those who believe that theater nuclear weapons are important to retain flexibility and maintain a credible deterrent.

CHAPTER IV

COSTS OF THE OPTIONS

To save money when possible is one of the most important goals of arms control, particularly among countries for which war does not seem imminent. This goal of arms control, first emphasized by Schelling and Halperin three decades ago, is particularly relevant to two countries currently enduring their most severe budgetary and economic crises of the postwar era.[1] For the Soviet Union, unable to arrest a fall in an already low gross national product and unable to assure its own population of a reliable food supply, the need for economic reform is plain (see Box 4). But the United States has pressing needs as well, and is currently saddled with an economy whose potential for growth is expected to be very modest by historical standards. Deep cuts in nuclear forces may free up enough resources to help both countries make substantial improvements in their economies.

MEASURES OF COST USED IN THIS STUDY

This study organizes nuclear costs into six main categories:

- Strategic offensive systems;
- Theater offensive systems;
- Nuclear warheads for strategic and theater offensive systems (Department of Energy activities);
- Nuclear command, control, communications, and intelligence systems;

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[1] Thomas C. Schelling and Morton H. Halperin, *Strategy and Arms Control* (Washington, D.C.: Pergamon-Brassey's, 1985; first printed by the Twentieth Century Fund in 1961).

- Arms control compliance and monitoring activities; and
- Defensive systems.

The costs of nuclear forces result primarily from acquiring new systems and from operating and supporting existing systems. Acquisition costs include funds to develop nuclear systems, procure the systems, and build the facilities needed for storage and operation of the systems. These costs are paid for out of research, development, test,

BOX 4
Can Cuts in Spending for Arms Help the Soviet Economy?

The Soviet economy faces a bevy of economic problems, some of which could be eased with the help of reductions in spending for arms. However, the economic benefits from such reductions are likely to be limited, especially in the short term.

Intractable long-term problems bedevil the economy--problems such as slow growth in productivity and standards of living, insufficient production of consumer goods, disruptions in the system for distributing food and other goods, and a lack of legal, technical, and other institutions that are needed to allow the Soviet Union to convert quickly to a market economy. More recently, other critical problems have emerged, such as a sharp decline in production, sharp increases in inflation, and severe shortages of many consumer goods. Recent estimates (which are generally thought to be conservative) suggest that Soviet gross national product fell by 8 percent between the first quarter of 1990 and the first quarter of 1991, and that some prices that were not subject to central control climbed by 71 percent over the same period. Adults in the Soviet Union are now estimated to spend an average of 25 percent of their waking hours waiting in line to buy goods. This figure is an indication of the severity of shortages, and of the high effective prices--prices measured in terms of time rather than money--that can emerge even when money prices are controlled.

Some possibility of achieving economic benefits arises from reduced spending for defense in the short term. Reductions in military spending could free Soviet industry to produce more arms for export, and thus to earn critically needed foreign exchange. Cuts in defense spending may also help reduce the yawning deficit in the central government's budget. A lower deficit might then allow a reduction in the growth of the money supply. The supply of money has been growing rapidly in recent months because the central bank is lending to the government to finance its deficit. Any success in and evaluation (RDT&E) accounts, procurement accounts, and military construction accounts, respectively. Operation and support (O&S) funds pay military and civilian personnel and cover other expenses such as fuel, spare parts, and equipment modifications.

This study estimates the average annual or "annualized" costs of U.S. nuclear forces. It employs average annual costs simply because it is easier to compare them with the overall defense budget, which is usually discussed in terms of an annual level of funding. Calculating

slowing this growth could lead to lower inflation and a reduction in related problems, such as shortages.

Still, the potential for such economic benefits is small. Overseas markets for Soviet arms may now be limited and, in any case, an expansion in exports of arms could backfire by reducing Western aid to the country. Moreover, it may well prove impractical to reduce the budget deficit by cutting defense spending because much of the Soviet economy is still centralized and depends on the central government for support. If the government reduced its military spending, defense workers would have no place to go unless the government itself provided new work for them. But such steps would mean little or no reduction in the deficit--and little short-term economic benefit.

Less Soviet spending for defense could help improve living conditions if the government transferred the resources that defense absorbs into new uses, but even here the prospects are limited. Some of the resources that are devoted to defense could help expand production of consumer goods by alleviating shortages of raw materials that constrain production in some areas. Still, the dearth of consumer goods does not result only from shortages of raw materials. Instead, scarcities on shelves in some areas stem partly from problems in transportation and distribution, and from the effects of artificially low state-controlled prices that have failed to reconcile supply and demand in these markets. Reduced spending for arms may not help solve these problems beyond a minor extent.

In the longer term, however, some benefits may arise from reduced defense spending through expanded investment. Plants and transport systems must be modernized, repaired, and extended, and much effort and money must be invested in training the Soviet people in new ways of doing things. Over the long term, reduced spending for defense could provide some of the materials that this investment will require, both by freeing domestic resources and by increasing flows of aid from the West.

annualized costs is a relatively simple matter. Taking operation and support costs as an example, first calculate annual operation and support costs for each year. These costs vary from year to year for a given option, since some weapons are gradually procured and others gradually retired. Then add the individual annual figures over the time period at issue--15 years in this study, for fiscal years 1992 through 2006--and divide by the number of years in that period to find a typical annual O&S cost. Calculate acquisition costs similarly.

The basic time frame of 15 years captures future plans as far as one can foresee most of them with some level of confidence. The 15-year period is also intended to give a sense of what long-term, steady-state costs for strategic forces of different sizes might be.

CBO bases its cost estimates on the assumption that all budgetary actions from fiscal year 1992 onward will be consistent with the characteristics of whichever force posture is ultimately chosen for the next 15 years. Thus, CBO assumes procurement plans will face a change beginning in fiscal year 1992 to reflect the assumed option. Further, it assumes any weapons in excess of treaty ceilings would be retired over the seven years beginning in fiscal year 1992, which is the period permitted for reductions under the START treaty. In accord with the President's September initiative, the Minuteman II force is assumed to be retired by fiscal year 1995.

For the options that include some type of post-START treaty, this approach could overstate savings somewhat. A post-START treaty would probably require some time to negotiate, even once a consensus had formed in the United States on what the proper goals for such a treaty should be. Still, a post-START treaty could happen quickly if START is ratified soon and if the Soviet or post-Soviet Union stabilizes. In that case, the Congress and the Administration may respond to fiscal pressures by carrying out at least some changes in U.S. strategic forces unilaterally even before a new treaty is completed.

Thus, it may be more realistic to assume near-term changes in U.S. policy than it would first appear; in the event of such changes, savings in budget authority of over $5 billion per year could be realized immediately under some options (see Appendix A). Moreover, the choice of a 15-year time frame for analysis tends to deemphasize the importance of what may happen in any given year or two. And finally, as discussed at the end of this chapter, escalating costs probably would drive up the costs of the Administration's planned force posture more than they would push up the costs of the options. If so, relative savings under the options could well be as great or greater than those estimated here.

CATEGORIES OF COSTS AND METHODS OF ESTIMATING

CBO estimated costs in six broad categories ranging from strategic offensive systems to defensive systems. This section describes each category and briefly describes the method used to estimate costs in each category. (For more detail on many of the costs, see Appendix A.)

Strategic Offensive Systems

This category includes major strategic offensive systems in each element of the strategic triad--such as the B-2 bomber and associated munitions, the Trident submarine and associated missiles, and the MX and Midgetman intercontinental ballistic missiles. Most costs associated with these major strategic offensive systems can be estimated explicitly for the individual weapons system at issue.

Also included under this heading are the costs of the fleet of KC-135 tankers used to provide aerial refueling for strategic bombers, basic research costs associated with strategic systems, and modification costs needed to keep existing systems reliable and effective--such as the $3 billion that the Air Force plans to spend on the Minuteman III force over the next 15 years.

Under the Administration's plan, costs to develop, buy, and operate major strategic offensive systems would average about $16 billion per year over the next 15 years (see Table 9). These strategic costs represent about one-third of the total nuclear budget. They are divided about evenly between acquisition costs and operation and support costs, and would be distributed among all three legs of the triad.

A number of assumptions come into play in this category of costs. Costs for tanker aircraft, about $1.5 billion annually at present, decline somewhat as the number of strategic bombers declines, but not quite proportionately because of other demands on the tanker fleet. Basic research costs, assumed to be about $1 billion, do not vary among the options. Modification costs run at $2 billion per year under the Administration's plan, and are scaled roughly to the number of weapons platforms for other options.

TABLE 9. U.S. AVERAGE ANNUAL NUCLEAR COSTS UNDER THE ADMINISTRATION'S CURRENT PLAN, 1992-2006
(In billions of 1992 dollars)

Cost Category	Average Annual Cost
All Nuclear-Related Activities Except Deployed Strategic Defenses	
Strategic Offense	15.7
Theater Offense	1.5
Nuclear Warheads	13.4
Nuclear Command, Control, Communications, and Intelligence	8.0
Arms Control Compliance and Monitoring	0.2
Air Defenses	2.0
Strategic Defense Initiative--Research and Development and Tactical Missile Defense Initiative	3.0
Subtotal	43.8
Deployed Strategic Defenses	
Strategic Component of GPALS	3.1
Phase I	2.2
Subtotal	5.3
Total with Deployed Strategic Defenses	
Total	49.1

SOURCE: Congressional Budget Office.

NOTE: GPALS = Global Protection Against Limited Strikes; Phase I = first stage of a large defense system against a ballistic missile attack.

In many cases, Department of Defense (DoD) documents provided the information necessary to arrive at these estimates. In some cases, CBO made assumptions about appropriate production rates and unit costs for various options. Generally, CBO assumed efficient production rates whenever possible. The unit cost of operating a particular weapon under the Administration's plan provides the basis for operation and support costs, even though some economies of scale may be lost when a program is scaled back.

Costs under various post-START treaties could deviate from the estimates made here if different approaches to arms reductions were taken. For example, CBO's options would reduce warhead loadings on submarines by reducing the number of warheads on individual missiles, even though such an approach would not physically prevent a country from rapidly reloading warheads onto downloaded missiles in a breakout scenario. To avoid this potential problem, submarines could be reconfigured so that each would carry fewer missile tubes. Some of the tubes could be filled with concrete, sealed on the top, or, most desirable of all, physically removed from the submarine. The Department of Defense has indicated to CBO that it is possible to carry out even this latter procedure without affecting the capabilities of U.S. submarines. Costs could reach several billion dollars to modify the entire submarine fleet in this way, but such sums would not be particularly onerous if spread out over a decade or so. Thus, this alternative could be considered in the future.

Under Options III and IV, costs could increase by several hundred million dollars per year if, rather than cancel the B-2 bomber program immediately, the United States were to finish the 15 aircraft already authorized in order to have them available for conventional missions. But even if this were done, these extra costs would not be attributable to the nuclear force posture, so they are not included here.

Theater Offensive Systems

Theater weapons are defined here to include all nuclear weapons except strategic (or intercontinental) weapons. The category of theater weapons includes weapons sometimes called tactical nuclear weapons, naval nuclear weapons, and intermediate or medium-range nuclear weapons. Examples of theater weapons that will not be destroyed under the President's 1991 initiative include bombs delivered by aircraft and the nuclear-armed variety of the sea-launched cruise missile (SLCM), also referred to as the TLAM-N for Tomahawk land-attack missile, nuclear.

These systems overall constitute a relatively small related category of costs--perhaps 3 percent of the nuclear budget. The expenditures that do occur arise from developing and procuring the few shorter-range weapons systems dedicated to nuclear weapons delivery, as well as from security and maintenance measures that the Department of Defense must carry out to safeguard the actual munitions designated for short-range use. CBO estimates that current Department of Defense costs for these systems are in the range of $1.5 billion per year. This number is scaled for the post-START options.

Nuclear Warheads

Costs in this category include expenses for the design, testing, production, and maintenance of nuclear warheads. The Department of Energy (DOE) incurs them, having the responsibility for these functions. (Some other Department of Energy costs, of modest overall size, are discussed below in the section on arms control compliance and monitoring.)

CBO assumes that the costs of nuclear weapons under current plans would average about $13.4 billion a year over the next 15 years, which represents roughly 25 percent of total nuclear spending. Of this amount, about $5.5 billion would be for environmental restoration and waste management, and $0.4 billion for basic research on verification technologies and on control technologies intended to enhance nuclear safety. These sums are not varied in the options. Nevertheless, these are nuclear-related costs that will have to be incurred over the next 15 years, and thus are included within the general scope of this study.

Thus, out of DOE's budget, only $7.5 billion a year can be tied to future weapons programs. Of this annual amount, about $2 billion is for research, development, and testing related to weapons; $2 billion is for materials production; yet another $2 billion is for weapons production; $1 billion is for planned reconfiguration of the nuclear weapons complex; and $0.5 billion is for new production reactors.

For purposes of this study, CBO assumes that $1.2 billion of the $4 billion in the total DOE budget for producing materials and warheads is variable, proportionate to the number of warheads maintained in the arsenal. This estimate is derived from statistical analysis of historical data and other techniques.

Reconfiguration of the entire Department of Energy infrastructure is also a variable that changes from one option to the next. The Department of Energy is currently studying the ways in which reconfiguration might be done, but some preliminary results are available. Under the lowest stockpile scenario in DOE's plans for the future, which is akin to CBO's Options III and IV, projected costs would be about 20 percent lower than for a stockpile nearly as large as today's.

In addition, CBO assumes that research and development costs relative to weapons could be reduced by up to $0.5 billion if fewer new warhead designs were needed. Finally, CBO assumes that DOE can defer construction of a new production reactor well beyond the time frame of this study for Options III and IV. The reason is that any cut in nuclear forces greater than 75 percent should allow at least a 25-year hiatus in tritium production, since tritium can be reclaimed from retired warheads and reused. (This calculation--done entirely without access to classified documents--is based on the assumption that the average tritium content of those warheads being retired is comparable with that of the warheads being retained.)

Putting all these areas together, options that deeply cut warheads should lead to multibillion-dollar annual savings in the Department of Energy's nuclear warhead activities. Savings could be as great as $2.3 billion annually.

Nuclear Command, Control, Communications, and Intelligence

Partly hidden from view by security classification practices, the facilities that provide command, control, and communications (C^3) for nuclear weapons, along with related intelligence gathering and processing (C^3I), are an extremely important yet often invisible part of the total nuclear budget.

CBO assumes that under the Administration's plan, nuclear C^3I would consume an average of about $8 billion a year over the next 15 years, about 25 percent of total C^3I spending, and about one-sixth of total nuclear spending. Total U.S. military spending for command, control, communications, and intelligence--for nuclear, conventional, and general purpose functions--is slightly more than $30 billion annually, of which about $20 billion is for C^3 and slightly more than $10 billion for intelligence. CBO's $8 billion estimate for nuclear C^3I includes about $5 billion for nuclear command, control, and communications, based on DoD's method of allocating these types of costs among nuclear and other functions. An estimated $3 billion per year is assumed to go to nuclear-related intelligence activities; this amount represents about the same share of total intelligence spending as nuclear C^3 represents of total Pentagon spending for command, control, and communications.

Costs associated with command, control, and communications are assumed not to vary appreciably among the options in this study. C^3 performs important functions such as surveillance for early warning of a missile attack, and is critical for security and safety. In addition, new types of threats--such as cruise missiles with low radar visibility--may require new types of surveillance technologies in the future. But intelligence costs are assumed to vary, declining significantly under the options that maintain the smallest number of warheads. This decline reflects CBO's assumptions that, under options that deemphasized nuclear weapons in general and nuclear counterforce doctrine in particular, there would be less need to buy extra satellites largely devoted to finding Soviet mobile ICBMs. Moreover, the options that deemphasized counterforce would also include a number of on-site monitoring techniques that would constitute a valuable supplemental form of intelligence (see the next section of this chapter and Chapter VI).

Although detailed plans are classified, it is plausible to assume that the intelligence community is planning to launch at least one imaging satellite every other year that would be devoted primarily to strategic functions. This assumption is derived as follows. The Administration's goal is reportedly about six to eight imaging satellites on station at any one time. By contrast, the historical mean reportedly is two to three imaging satellites; the increase in the Administration's goal over this historical average is believed to arise largely from a heightened emphasis on targeting nuclear systems such as mobile missiles.[2] If one assumes that the United States would maintain only three satellites under Options III and IV, the differential between the Administration's plan and Options III and IV would be about four satellites on station. Assuming satellite lifetimes to be somewhere between four and eight years implies a difference on average of at least one satellite launch every other year. The average cost of a satellite and its launch rocket is perhaps $1.25 billion, implying that the average annual savings under Options III and IV would be at least $0.6 billion and perhaps more.

Moreover, with fewer weapons--and fewer weapons types--there would be less weapons testing, less weapons movement and training, and a smaller Soviet infrastructure involved with nuclear forces. Consequently, it would be easier to cut U.S. intelligence personnel in accordance with the Armed Services Committees' fiscal year 1991 conference report mandating 25 percent cuts in intelligence personnel over the next five years. This area would yield additional savings for the options that cut nuclear forces heavily.

Arms Control Compliance and Monitoring Activities

As discussed in Chapter VI, several different specific methods could be used to verify future nuclear arms treaties and to comply with treaty requirements. These methods include activities such as making routine inspections at military bases, continuously surveying major weapons production sites, observing the other country destroy its excess systems, destroying one's own excess weapons, and preparing one's own bases and factories for inspections. The United States already spends perhaps $100 million a year for these activities under the U.S.-Soviet Intermediate-Range Nuclear Forces Treaty, and again as much under the U.S.-Soviet nuclear test ban treaties.[3]

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[2] See Congressional Budget Office, *U.S. Costs of Verification and Compliance Under Pending Arms Treaties* (1990).

Under the START treaty, the costs of these types of activities would grow somewhat, to perhaps $500 million per year. If one of the more ambitious treaties discussed in this paper were carried out, such activities could reach a total of about $1 billion. Total costs for verification and compliance activities specific to existing arms control agreements are less than 1 percent of the nuclear budget today, but could increase to 3 percent under some options. The on-site inspections would partially offset the decreased number of intelligence assets discussed above, providing a relatively inexpensive type of monitoring capability.

Defensive Systems

Defensive systems include those small air-defense systems the United States has had in place for decades, basic research and development on new technologies that could be useful in defense against either bomber or missile attacks, defenses against short-range or tactical missiles, and defenses against long-range or strategic missiles. It is the latter category of defensive systems--deployed defenses against long-range missiles--that is especially contentious in the debate over the Strategic Defense Initiative.

Spending for bomber defenses, tactical missile defenses, and basic research on strategic defenses is held constant throughout all options. All of the options assume expenditures of $2 billion for the air defense of North America. They also assume costs for research on basic technologies relevant to missile defense of $2 billion a year. Finally, they include estimated spending by the Strategic Defense Initiative Organization of $0.7 billion a year to develop defenses against shorter-range missiles, as well as about $0.3 billion a year to operate and support these tactical defenses.[4] The sum total of all these figures--$5 billion--is the annual funding level assumed in all the options for these types of defensive systems and activities.

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[3] See Congressional Budget Office, *U.S. Costs of Verification and Compliance*, pp. 18 and 35.

U.S. plans for deploying strategic defense systems are more complicated to discuss and analyze. Because the issue of deployed strategic defenses remains highly controversial, it is treated specially in this study. In particular, cost totals for each force posture are calculated with and without deployed strategic defenses. In cases that assume strategic defenses will be deployed, the size and nature of the defenses vary from option to option.

To be specific, costs for deployed strategic defenses would vary over the options by more than $4 billion per year. Under the Administration's plan, they could reach $5.3 billion per year on average over the next 15 years, assuming that Phase I would be deployed in that time. For Option IV, in which only a small defense against accidental launch or third-party launch would be deployed, costs would be about $1 billion per year.

To understand these figures better, consider the following factors. Over the next 15 years, just acquiring the strategic defense elements of the Global Protection Against Limited Strikes system would cost about $38 billion in 1992 dollars. This total figure includes about $12 billion for space-based interceptor rockets known as brilliant pebbles. The remaining $26 billion would be spent on ground-based strategic defenses. (The $10 billion for theater defenses that also would be part of GPALS spending is already accounted for above and is not included in the strategic defense part of GPALS.) These strategic parts of GPALS would average about $2.5 billion a year in acquisition costs. Operation and support costs would add $0.6 billion annually, making the GPALS total about $3.1 billion a year for strategic defenses.

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[4] This CBO estimate is based on aggregate data the Strategic Defense Initiative Organization provided to CBO. A total of $0.9 billion in annual operation and support costs was assumed to be equally divided among three categories: tactical or theater defenses, ground-based strategic defenses, and space-based strategic defenses. For Phase I of SDI, an additional $0.6 billion per year in average operation and support costs was assumed, again based on Department of Defense data.

Additional acquisition costs associated with the larger Phase I system of defenses might amount to $24 billion, or about $1.6 billion annually. Additional operation and support costs would add about $0.6 billion per year. These numbers are based on optimistic assumptions about the ability of the Strategic Defense Initiative Organization to realize large economies of scale in its procurement and operation of weapons. Thus, the marginal cost of Phase I, assuming GPALS is already deployed and paid for, would be about $2.2 billion per year on average.

The post-START options vary in the amount of funds allocated for the strategic part of GPALS. None of the post-START options would include Phase I; all would include some form of GPALS, though for Options II, III, and IV the GPALS system would be scaled back relative to the Administration's current plan.

COSTS AND SAVINGS UNDER DIFFERENT OPTIONS

As noted above, the uncertain status of strategic defenses complicates this study's treatment of costs and savings. In particular, while the Administration's plan calls for not only a limited GPALS system, but also a large Phase I strategic defense system, both of these systems would require abrogation of existing U.S. treaty commitments. GPALS, or some part of it, might well be made consistent with a modified version of the ABM treaty, should the United States and a successor to the Soviet Union be able to negotiate such a modification. But Phase I would be fundamentally inconsistent with the conceptual framework of the ABM treaty, and with traditional approaches to offensive arms control as well.

Not yet clear is how the President and the Congress together will solve these problems. Nevertheless, because GPALS and Phase I are part of the official budget plan, this analysis cannot ignore them. For this reason, the basic approach of this chapter is to assume that GPALS and Phase I would be deployed under the Administration's plan, though a brief explanation of how costs and savings would change without strategic defenses is also included below.

At a minimum, the Administration's plan would require about $44 billion a year for nuclear programs. The largest components of this total are funding for strategic offensive weapons ($16 billion), nuclear warheads ($13 billion), and strategic communications and intelligence ($8 billion). But the Administration's plans for a GPALS system would add another $3 billion and bring the nuclear budget to nearly $47 billion. Its plans for a large Phase I strategic defense system would add about $2 billion and bring the nuclear budget to about $49 billion a year (see Table 9 on page 62).

Savings from the START Treaty

Compared with the Administration's current plan, the START treaty would not guarantee large savings. Savings would amount to a few hundred million dollars per year in costs the Department of Defense bears to operate the forces, and possibly in costs the Department of Energy bears to build and maintain nuclear warheads. But these savings could be wholly or partially offset by additional costs associated with verifying the treaty and complying with its stipulations. These estimates are based on the assumption that the Pentagon would comply with START by carrying out its current plan, and in addition reducing the number of warheads carried on some Minuteman III missiles. Eventually, once the small ICBM became available, some Minuteman III missiles would be retired under this plan.

These estimates are also based on the assumption that the United States would derive no budgetary benefit from selling surplus ICBMs and SLBMs for space-launch missions. Because the Administration appears to place a high priority on commercializing the space-launch market, it is not expected to put surplus ballistic missiles up for sale.

Although the proposed START treaty would not guarantee large budgetary savings, the negotiations leading to the treaty may have already led the United States to reduce its planned nuclear forces. In January 1990, the Administration submitted a plan for U.S. nuclear forces that was formulated during the Cold War. That plan called for producing more Trident submarines than are now planned (probably 23 rather than 18) and more Trident II D5 missiles than will now be needed; moving 50 MX missiles to rail cars and continuing production of test missiles; deploying 132 B-2 bombers compared with the 75 bombers now planned; and procuring a small mobile ICBM. The average annual cost of that plan would have amounted to more than $56 billion a year (see Appendix A). Compared with the earlier plan, the START treaty would save nearly $7 billion annually.

Savings from the President's Initiative

On September 27, 1991, President Bush proposed a number of unilateral changes in U.S. nuclear forces (see Box 2 in Chapter III). Compared with the Administration's plan submitted in early 1991, the annual savings associated with these unilateral changes could average about half a billion dollars over the next 15 years. The budgetary implications of this initiative are incorporated into CBO's estimate of the cost of the Administration's current plan. Most of the savings are associated with eliminating the mobile basing mode for the small ICBM, which reduces costs to develop and buy this system.

Savings from Post-START Options

Although the proposed START treaty would not guarantee substantial savings compared with the Administration's current plan, some of the post-START options would. On an annual basis, Option I might save more than $2 billion, Option II more than $9 billion, Option III more than $15 billion, and Option IV more than $17 billion (see Table 10).

Savings under Option I would arise mostly in the missile defense realm, where savings compared with the Administration's plan would be $2.2 billion annually. The other options would save $3.3 billion, $3.6 billion, and $4.3 billion, respectively, in the realm of GPALS and Phase I.

Options II, III, and IV would also save significant sums in the area of strategic offensive forces. Reducing both procurement of new systems and operation costs associated with existing systems could yield savings of nearly $5 billion a year under Option II, and nearly $9 billion annually for Options III and IV.

Moderately large savings might also stem from three other realms--nuclear warheads (Department of Energy activities); strategic command, control, communications, and intelligence; and theater weapons. In the area of nuclear warheads, average savings under Op-

TABLE 10. U.S. AVERAGE ANNUAL COSTS AND SAVINGS UNDER POST-START OPTIONS, 1992-2006 (In billions of 1992 dollars)

		Savings Under Post-START Options			
Cost Category	Cost of Administration's Current Plan	I. Ban Heavy ICBMs, Limit Defenses	II. Reduce Strategic Warheads to 6,000	III. Reduce Strategic Warheads to 3,000	IV. Reduce Strategic Warheads to 1,000
All Nuclear-Related Activities Except Deployed Strategic Defenses					
Strategic Offense	15.7	0.2	4.8	8.6	8.7
Theater Offense	1.5	0	0.5	1.0	1.5
Nuclear Warheads	13.4	0.2	1.1	2.0	2.3
Nuclear C^3I	8.0	0	0.2	1.2	1.5
Arms Control Compliance and Monitoring	0.2	-0.3	-0.6	-0.9	-0.9
Air Defenses	2.0	0	0	0	0
Strategic Defense Initiative--Research and TMDI	3.0	0	0	0	0
Subtotal	43.8	0.1	6.0	11.9	13.1
Deployed Strategic Defenses					
SDI--GPALS Only[a]	3.1	0	1.1	1.4	2.1
SDI--Phase I	2.2	2.2	2.2	2.2	2.2
Subtotal	5.3	2.2	3.3	3.6	4.3
Total with Deployed Strategic Defenses					
Total	49.1	2.3	9.3	15.5	17.4

SOURCE: Congressional Budget Office.

NOTES: ICBMs = intercontinental ballistic missiles; C^3I = command, control, communications, and intelligence; TMDI = Tactical Missile Defense Initiative.

a. Includes funds for the strategic component of the Global Protection Against Limited Strikes (GPALS) system, a part of the Strategic Defense Initiative (SDI).

tion IV could be more than $2 billion. Savings for communications and intelligence could be about $1.5 billion a year under Option IV and almost as much under Option III. Savings for theater weapons would be as great as $1.5 billion.

Modest cost increases could stem from treaty verification and compliance, as discussed in more detail in Chapter VI. Additional costs could approach $1 billion a year. This amount would be relative to the current situation in which both the Intermediate-Range Nuclear Forces Treaty and the nuclear test ban treaties are being verified, at a total cost of perhaps $200 million annually.

Savings under these options would be even greater were it not for the high priority they accord to maintaining multifaceted and modern weapons platforms. These platforms should provide the United States with a highly survivable nuclear deterrent, but they do cost large sums to acquire and operate. Even under Option IV, the United States would continue to spend almost as much on its nuclear forces as Germany, France, or Britain spends on its entire military. Were the United States to determine that security could be ensured with somewhat less capable forces, savings could be even greater.

Costs and Savings with No Deployed Strategic Defenses

As noted above, the Anti-Ballistic Missile Treaty--rooted in strong strategic arguments that may or may not remain fully relevant to the 1990s--may make it particularly hard for the Administration to convince the Congress to carry out its strategic defense plan. In this case, because the Administration's plan would become considerably less expensive, the relative savings associated with the post-START options would decline.

For example, the option that assumes a reduction to 1,000 warheads (Option IV) would result in annual average nuclear savings of roughly $13 billion relative to the Administration's current plan. A reduction to 3,000 warheads (Option III) would result in savings of roughly $12 billion per year. These annual savings associated with the post-START options would be roughly $4.3 billion and $3.6 billion less than the total savings indicated in Table 10, in which defenses are included in the analysis.

COST UNCERTAINTIES

Although the cost estimates in this chapter should provide a reasonable guide to policymaking, several uncertainties could cause actual savings to deviate from the estimates. First, if the history of military budgets over past decades is indicative, the costs to acquire and operate planned systems are likely to escalate beyond the currently expected level. For example, were acquisition costs associated with strategic defenses to grow by 20 percent to 50 percent in real terms, the Administration's plan would cost about $1 billion to $2 billion a year more on average. The costs of environmental cleanup may also escalate above predicted levels because the extent of the pollution and the actual costs of cleanup are unknown at this time. The latter issue could increase costs under all postures discussed here. The former would make the costs of the Administration's plan and Option I exceed those of Options II, III, and IV by even more than they do in the current estimates; thus, relative savings could be even greater than indicated under the options that would cut nuclear forces deeply.

Certain estimates also contain a methodological imprecision, particularly those costs for strategic intelligence and those for the Department of Energy's production and maintenance of warheads. Because the full data are not available to the public, the actual costs in both of these categories are uncertain.

Despite these uncertainties, the earlier conclusions remain clear: START is unlikely to save much money compared with the Administration's current plan, though it would codify an improved state of superpower relations that already has led to considerable savings in nuclear budgets compared with those forecast as recently as 1990. Perhaps more important for future policymaking, significant additional cuts in nuclear arms could result in large budgetary savings that could exceed $15 billion a year when compared with current plans.

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CHAPTER V

NUCLEAR FORCES AND SIMULATED NUCLEAR WAR

The cornerstone of nuclear deterrence is a country's ability to retaliate after being attacked by an adversary. If either side were confident that it was capable of disarming the other in a first strike, or afraid that it might be disarmed by a first strike, the situation could create huge pressure to strike first during crises--a state called crisis instability.

With submarines at sea, missiles in hardened silos, and bombers that could be on alert, both the United States and the Soviet Union today would possess a significant retaliatory capability after absorbing a first strike. But under deep reductions of the type proposed in some of the options, would they still have sufficient retaliatory capability to deter war in the first place? This chapter addresses this question by mathematically simulating nuclear war under each of the options presented in this study.

Discussions about exchange calculations and target lists tend to take on a tone reminiscent of the Cold War, something that may seem inappropriate given the fundamental transformations that have taken place in U.S.-Soviet relations and in Soviet policy itself. But one must assume an attacker and an attacked to examine how effective military forces would be under various options. Regardless of how remote the possibility of a nuclear war is today, nuclear deterrence continues to be an important element of the relationship between the United States and the Soviet Union. Therefore, analyzing nuclear forces remains important, even if the terminology and the tone of the discussion seem anachronous (see Box 5).

BOX 5
The Terminology of Nuclear War

First Strike: The opening attack in a nuclear exchange.

Second Strike: A retaliatory strike by the side that was attacked first.

Second-Strike Capability (Retaliatory Capability): The ability to launch a retaliatory attack on an opponent with forces that survive a first strike. This capability depends not only on the number of surviving weapons, but on the state of the command and control systems that must deliver the launch order.

Hard Targets: Targets that are resistant to the effects of nuclear explosions. Hardness is usually expressed as the pressure in pounds per square inch (psi) of the shock wave that strikes the target, although hardness also includes a target's resistance to the nuclear radiation, heat, and dynamic overpressure that are part of a nuclear explosion.

Fratricide: Hard targets such as missile silos are often assumed to be targeted by more than one warhead to increase the probability that the target would be destroyed. Fratricide would occur if one of the incoming warheads destroyed or otherwise impaired one or more of the other warheads aimed at the target.

Barrage Attack: An attack in which many warheads would be exploded over a broad area to destroy soft targets that had been dispersed in the area. Barrage attacks are usually discussed in the context of attacks on mobile

Other factors may also influence judgments about the effectiveness of these options in deterring nuclear war. Some of these factors, including the effects of deep reductions on U.S. superpower status and on the effectiveness of extended deterrence, are discussed in Chapter VII.

METHODOLOGY AND ASSUMPTIONS

Many factors would influence the ability of U.S. or Soviet forces to survive an initial nuclear attack. For example:

missiles or on bombers flying away from their bases. It is also possible to barrage submarine deployment areas, but the vast ocean areas where submarines operate would require far too many warheads to be feasible.

Day-to-Day Alert: The everyday alert rate of nuclear forces in peacetime. An attack under these conditions would come without any warning of the type that might be provided by a serious crisis or signs of an opponent's mobilization or heightened alert. This sort of attack is often referred to as a surprise attack or "bolt-out-of-the-blue" attack.

Generated Alert: The heightened alert status that nuclear forces would maintain if a crisis or signs of an opponent's preparations for war made an attack seem likely. During a generated alert, more submarines would be at sea, bombers would be on runway alert, and more mobile missiles would be dispersed.

Reentry Vehicle (RV): The body that carries each intercontinental or submarine-launched ballistic missile warhead back into the atmosphere. This body protects the warhead from the stress and heat of reentry. The shape and composition of the RV affect the accuracy of the warhead.

Circular Error Probable (CEP): A measure of the accuracy of a missile or bomb. The CEP is defined as the radius of the circle within which 50 percent of the warheads would land if all were fired at the same target. Because the CEP is determined by particular weapon characteristics, there is a different CEP for each type of weapon.

- The ability of missiles based in silos to survive an enemy attack depends on the hardness of the silos and on the accuracy and size of the warheads that could attack the silos.

- The survival of mobile missiles, which are designed to be dispersed over a wide area in the event of a crisis, depends on the number of warheads that an enemy can muster and the ability of those warheads to effectively barrage the wide area that contains the mobile missiles.

- Since submarines at sea are largely invulnerable to attack but submarines in port are very vulnerable, the ability of the submarine force to survive depends on the number of submarines at sea. It also depends on the ability of missile submarines at sea to avoid being trailed by an adversary's attack submarines, something that may be difficult for some Soviet missile submarines.

- The ability of bombers to survive depends on how quickly they can become airborne and disperse over an area wide enough that an enemy attack cannot barrage it.

Scenario for an Attack

Calculating the number of warheads that would survive an enemy attack depends in part on the scenario for that attack. During a first strike, a primary goal of the attacker would be to destroy the defender's capability to counterattack with nuclear weapons. Consequently, the scenario in this study assumes that the attacker uses long-range nuclear systems to attack targets such as the defender's early warning and defense radars, silo-based missiles, bomber bases, mobile missile garrisons and deployment areas, submarine bases, command and control facilities, and other ports and airfields.

To improve the probability of destroying each target, two warheads are generally assumed to attack all hardened point targets, such as missile silos. Also, the attacker is assumed to use the best available systems against the most potent of the other country's systems: for example, because of the MX's high accuracy and large number of warheads, the Soviet SS-25 and SS-18 missiles are assumed to give first priority to destroying U.S. MX missiles. Submarine-launched ballistic missiles would be used to attack bomber bases and mobile missile garrisons during the first moments of the attack to catch the bombers and mobile missiles before they had a chance to disperse. The calculations in this study assume perfect timing between the different elements of the attacking forces, which may not be possible given the complexity of an attack. If the timing were less than perfect, the attack might not be as effective as is assumed in this analysis.

The attacks simulated in these calculations assume that the attacked country does not launch its missiles while under attack, either before the attacker's first warheads arrive or after the first confirmed nuclear detonation. Such strategies, called launch on warning and launch under attack, respectively, would considerably enhance the number of warheads that the attacked country could use to retaliate, but these strategies carry substantial risks. For example, if malfunctions in a country's missile warning systems caused a false warning of an attack, it could provoke that country to start a war inadvertently without being attacked, since the short flight time of ballistic missiles requires a rapid launch decision. Similarly, with either a launch-on-warning or launch-under-attack strategy, an accidental launch of a few missiles could lead to a massive response, again leading to unintended nuclear war.

Given these risks, this study assumes that neither side would launch on warning or under attack, despite reports that the United States includes launch under attack as one policy option. Nevertheless, an attacker could never rule out the possibility that the country under attack might have such a strategy, which would profoundly complicate an attacker's plans.

These initial exchange calculations also exclude ballistic missile defenses. Although defenses clearly could significantly alter the results of an exchange by reducing the effectiveness of both a first strike and a second strike, especially when the arsenals are small, deploying extensive defenses is controversial and currently prohibited by the ABM treaty. For these reasons, the effectiveness of defensive forces is examined in a subsequent section.

Soviet Modernization

The capabilities of each side also affect, of course, estimates of surviving warheads. Chapter III defined U.S. forces under each of the options analyzed in this study. The Soviet Union is assumed to match the numerical limits imposed on U.S. forces under each option, even though it now appears possible that, under the START treaty, the Soviet Union will make unilateral cuts in strategic weapons to levels below those of the United States.

This assumption includes a number of others. For example, within the numerical limits, the Soviet Union will continue to introduce new and more modern systems into its strategic arsenal. This modernization program will significantly improve the accuracy of Soviet land-based missiles to a level close to that of the current U.S. MX missile and the accuracy of Soviet submarine-launched ballistic missiles to roughly that of the current U.S. Trident I (C4) missile. The Soviet Union will also increase the size or yield of the warheads on submarine-launched ballistic missiles under those options in which the warheads on each missile are reduced in number (downloaded). (For more details about assumptions regarding Soviet forces, see Appendix B and Appendix D.)

Uncertainty in This Analysis

Many uncertainties are inherent in calculating nuclear exchanges. These uncertainties stem from the lack of data on the effects of nuclear weapons, limited atmospheric nuclear testing, and other physical phenomena that can affect the outcome.

One source of uncertainty is fratricide (one warhead degrading the effectiveness of subsequent warheads aimed at the same target, either through blast, radiation, or debris clouds).[1] Standard calculations usually neglect fratricidal effects altogether, which results in a higher calculated probability that hardened targets such as silos would be destroyed. But as then Secretary of Defense Harold Brown pointed out in his 1979 Annual Report, fratricide is a problem that must be accounted for in planning for nuclear war.[2]

An even more important factor is the degree of surprise the attacker could achieve. With little or no warning, many of the attacked country's submarines would be in port, most or all of its bombers would be at low levels of readiness, and mobile missiles would not be dispersed over wide areas. The attacker, however, would have its assets deployed or dispersed. Thus, in a surprise attack, many of the attacked country's assets would be destroyed. If, however, an attack occurred after considerable warning, many more of the attacked country's assets would be dispersed and so would be likely to survive the attack.

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[1] See Matthew Bunn and Kosta Tsipis, "Ballistic Missile Guidance and Technical Uncertainties of Countersilo Attacks," Report Number 9, Program in Science and Technology for International Security, Department of Physics, Massachusetts Institute of Technology (August 1983), especially Part II, for a full discussion of fratricide. See also Bunn and Tsipis, "The Uncertainties of a Preemptive Nuclear Attack," *Scientific American* (November 1983).

[2] Department of Defense, *Annual Report: Fiscal Year 1979* (February 2, 1978), p. 63.

These scenarios do not include a surprise attack by sea-launched cruise missiles or bombers because the assumption is that these platforms are slow enough and could be detected early enough that the attacked country's forces could be placed on alert well before nuclear detonations would occur.[3]

Other Uncertainties

Although this study reflects the effects of some uncertainties, CBO's estimates do not reflect many others. There are uncertainties in missile accuracy, warhead yield, bomber hardness, and the timing of attack. CEP, the circular error probable of a missile, is a measure of how accurately each warhead hits its target. The CEP quoted for each missile system can be uncertain for two reasons: first, actual CEP values are classified, and consequently the quoted values are unclassified estimates that experts glean from the public record; second, for obvious reasons, the missiles have not been tested over the trajectories they would fly during an attack.

Warhead yield, the explosive power of each warhead, is uncertain primarily as a result of limited testing. According to Defense Intelligence Agency data, warhead yield could be 10 percent more or less than the cited figure.[4] Bomber hardness, a bomber's ability to withstand nuclear blast and radiation effects and still perform its mission, is not known with certainty because the Limited Test Ban Treaty of 1963 prohibits the testing of nuclear weapons in the atmosphere, making realistic testing impossible.

Moreover, the attack scenarios used in this study are necessarily a simplified version of what might happen during a first strike. The exact details of the Soviet and U.S. war plans are closely guarded secrets.

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[3] See, for example, David Fulghum, "Welch: Launching of B-2s Wouldn't Surprise Soviets," *Air Force Times* (March 5, 1990), p. 8.

[4] Bruce W. Bennett, "How to Assess the Survivability of U.S. ICBMs," R-2577-FF (RAND Corporation, Santa Monica, Calif., June 1980), p. 35.

Finally, many uncertainties beset the operational use of nuclear weapons that remain because these weapons have never been tested under realistic conditions. Prime among these is the extent to which an attack would degrade command and control capabilities.

All these uncertainties suggest that the reader should use the estimates in this study as rough guides rather than as precise estimates of what would happen in the event of a nuclear attack.

SURVIVING WARHEADS WITHOUT DEFENSES

If there were no system of defenses, how many warheads would survive an enemy first strike? This section estimates the number of surviving warheads for a Soviet first strike on the United States and a U.S. first strike on the Soviet Union, assuming that strategic ballistic missile defenses have not been deployed. The purpose of looking at a first strike is to illustrate the survivability of U.S. and Soviet forces, which is important to ensuring crisis stability. This exercise is not meant to suggest that either the United States or the Soviet Union would launch a first strike. Nevertheless, since the paramount function of U.S. nuclear forces is to deter such a strike, it is essential to evaluate them in this context.

The setting for these calculations is the year 2006, when the changes under the study's options are assumed to be complete. Table 11 includes the survivability of current forces, defined as the forces that the United States and the Soviet Union have in early 1991. This force posture is included to demonstrate how the illustrative START and post-START postures would compare with the forces currently deployed. Using today's forces here can provide an important baseline from which to judge the deterrent capabilities of the START and post-START options.

Results for U.S. Forces

A high percentage of U.S. forces would survive a Soviet first strike under all options. The lower end of the range of estimates, which represents the worst case for the defender, shows that 21 percent to 39 percent of total U.S. warheads would survive a withering Soviet attack, depending on the option. At the upper end of the range, which represents the best case for the attacked country, 46 percent to 77 percent of total U.S. warheads would survive.

High survivability convinces an adversary that no gain is to be had in striking first. Thus, a force with a high percentage of survivability would contribute to stabilizing a crisis and at the same time could achieve the desired retaliatory capability with smaller forces.

Although the percentage of warheads that would survive a first strike is a useful measure for stability, the absolute number of surviving warheads is also important to the extent that each side must have sufficient forces to execute its retaliatory attack (second strike). The number of warheads required for a second strike is directly affected by what each side believes is necessary to deter its opponent. The issue of second-strike forces is addressed in the next section and in Chapter II.

CBO's lower and higher estimates of the survivability of weapons reflect different assumptions about the degree of surprise and the effects of fratricide. The lower estimate (the worst case for the defender) assumes a surprise attack with no fratricide. A surprise attack would mean that the attacked country would be on what is termed day-to-day alert, with many of its submarines in port and its bombers at their bases in a low state of readiness. During day-to-day alert, the attacked country is assumed to have all its ICBMs on full alert, its road-mobile missiles on alert but constrained within deployment areas defined by treaty, and its rail-mobile missiles within their garrisons. For the United States, approximately 67 percent of its submarines would be at sea ready to fire within a few hours (55 percent for Poseidon submarines), and--as a consequence of President Bush's September 1991 initiative--none of its bombers would be on runway alert. For the Soviet Union, 15 percent to 25 percent of its submarines would be at sea and none of its bombers would be on alert. Thus, many of these bombers and submarines would be easily destroyed.

This scenario also assumes that the attacker's submarines are able to get close to the other country's coasts without being detected and alerting the country about to be attacked. Having its submarines near the coast would allow the attacker to minimize the flight time of submarine-launched missiles and the warning time given to the attacked

TABLE 11. NUMBER OF STRATEGIC WARHEADS THAT WOULD SURVIVE A FIRST STRIKE

	Soviet First Strike		
Plan or Option	U.S. Warheads Before Attack	Surviving U.S. Warheads	Percentage of Initial U.S. Warheads Surviving
Forces as of Early 1991	12,900	4,800 to 8,200	38 to 64
Administration's Plan and Variation			
Administration's Current Plan	11,500	2,400 to 5,300	21 to 46
Administration's Plan with START	10,500	2,400 to 5,200	23 to 50
Post-START Options			
I. Ban Heavy ICBMs, Limit Defenses	10,500	2,500 to 5,400	24 to 52
II. Reduce Strategic Warheads to 6,000	6,000	2,400 to 4,500	39 to 74
III. Reduce Strategic Warheads to 3,000	3,000	900 to 2,200	30 to 74
IV. Reduce Strategic Warheads to 1,000	1,000	300 to 800	30 to 77

(Continued)

SOURCE: Congressional Budget Office.

NOTES: The ranges of surviving warheads reflect two different attack scenarios--a surprise attack and an attack during a crisis--as well as differing assumptions about fratricide.

ICBMs = intercontinental ballistic missiles.

country, thereby catching and destroying more bombers and mobile missiles at their bases. The assumption of no fratricide increases the probability that the attacker would destroy missiles in their silos because the two warheads aimed at each silo would not interfere with each other.

TABLE 11. Continued

	U.S. First Strike		
Plan or Option	Soviet Warheads Before Attack	Surviving Soviet Warheads	Percentage of Initial Soviet Warheads Surviving
Forces as of Early 1991	11,600	2,100 to 5,600	18 to 48
Administration's Plan and Variation			
Administration's Current Plan	12,100	1,300 to 4,700	11 to 39
Administration's Plan with START	7,600	600 to 3,200	8 to 43
Post-START Options			
I. Ban Heavy ICBMs, Limit Defenses	7,600	600 to 3,200	8 to 43
II. Reduce Strategic Warheads to 6,000	6,000	500 to 2,900	8 to 49
III. Reduce Strategic Warheads to 3,000	3,000	500 to 2,000	16 to 67
IV. Reduce Strategic Warheads to 1,000	1,000	400 to 800	42 to 83

NOTES: Continued

Were the Soviet Union to make further unilateral cuts in its strategic forces, numbers under the START plan could vary somewhat--especially the absolute numbers of surviving Soviet warheads under the assumption of a U.S. first strike.

The upper bound of the range of estimates of survivability, which represents the best case for the attacked country, assumes that the attack comes during a crisis and the attacked country has at least 24 hours of warning before the attack. In this case, the attacked country is assumed to have enough warning that it can place its forces on alert and disperse them before any attack begins. The attacked country is said to be on generated alert in this case. During a generated alert, all ICBMs are assumed to be on full alert, mobile missiles to be widely dispersed beyond the deployment areas limited by treaty, and all bombers to be on runway alert but not dispersed to alternate bases under CBO assumptions (although they could be). U.S. submarines are assumed to have about a 90 percent at-sea alert rate. The alert rates for Soviet ballistic missile submarines (SSBNs) are assumed to be 67 percent. Under this scenario, total fratricide is assumed as well, thereby reducing the effectiveness of multiple-warhead attacks on silos because only one warhead could explode over any one hardened target.

Although the range of estimates of survivability accounts for differences stemming both from the degree of surprise and from fratricide, this range does not explicitly account for uncertainties in CEP, yield, and other factors. Most of the difference in the range is the result of the amount of warning rather than the effects of fratricide. About 90 percent of the difference between the lower and higher estimates is explained by the amount of warning and about 10 percent by fratricide.

Were the Soviet Union to make unilateral cuts in its strategic arms, of the type proposed by President Gorbachev in October 1991, U.S. forces might be somewhat more survivable under START--depending on which weapons the Soviet Union chose to eliminate. However, it is also possible that further Soviet cuts could have little or no effect on the number of U.S. forces surviving.

Results for Soviet Forces

In most cases, Soviet forces would fare worse than U.S. forces against a first-strike attack, either today or by the year 2006 under all of the options (see Table 11 on page 86). The percentage of survivability ranges from 8 percent to 42 percent under the worst-case scenarios for the Soviet Union (compared with 21 percent to 39 percent for U.S. forces) and from 39 percent to 83 percent under the best case (compared with 46 percent to 77 percent for U.S. forces). These numbers might change somewhat if the Soviet Union made further unilateral cuts in its strategic forces.

Soviet operational doctrine primarily explains the lower survivability in the worst-case scenario for the Soviet Union. During normal or day-to-day conditions, the Soviet Union keeps most of its ballistic missile submarines in port and virtually all of its bombers unprepared to take off quickly. In contrast, the United States keeps two-thirds of its submarines at sea. In a surprise attack, then, almost all Soviet submarines and bombers would be destroyed.

One can explain the remarkably low number of Soviet warheads surviving during day-to-day conditions in the early 1991 force in one or more of several ways: Soviet leaders do not think a U.S. surprise attack is likely, they believe that small numbers of warheads are sufficient to deter an attack, or they rely heavily on launch under attack. If the Soviet Union were concerned about survivability in these day-to-day conditions, operational patterns could be changed relatively easily: bombers could be placed on runway alert, and more submarines could be kept at sea.

Soviet forces are also somewhat less likely to survive than U.S. forces in an attack that occurs with warning, though the differences are less noticeable. Lower survivability in this situation occurs for several reasons: first, U.S. forces are extremely accurate and therefore make good counterforce weapons; second, a large number of Soviet warheads are based in silos where they are vulnerable to attack by U.S. forces; and third, only two-thirds of the Soviet SSBN fleet is likely to be at sea. One explanation for the intense Soviet modernization of strategic offensive forces during a period of improved U.S.-Soviet relations is that the Soviet Union is behind the United States in survivability and will remain so even after this modernization is complete.

The differences between the survivability of U.S. and Soviet forces persist, but to a lesser degree, under options that reduce the number of warheads to low levels. In Option IV, however, all missiles have only one warhead, and warhead levels are low enough to make barrage attacks impossible. These factors tend to lead to high survivability for both U.S. and Soviet forces.

In sum, the percentage of U.S. warheads that are likely to survive a Soviet first strike is substantial and would actually increase--relative to the Administration's plan--under those options that reduced the total number of warheads, although the number of surviving warheads would decrease. Thus, the options in this study should not create apprehension that the United States might be placed in a situation where it would have to use its strategic warheads or lose them.

THE EFFECTIVENESS OF SECOND-STRIKE FORCES

As stated earlier in this chapter, under the Administration's plan about 2,400 to 5,300 U.S. warheads might survive a Soviet first strike, depending on the amount of warning and fratricide. About the same number would survive under the Administration's plan as modified to accommodate the pending START treaty. At the other extreme, about 300 to 800 warheads might survive under the option that reduces the superpower arsenals to 1,000 warheads. How well would these numbers of surviving warheads cover possible sets of targets?

As discussed in Chapter II, views vary drastically of the forces required to deter a nuclear attack. Options that would reduce warheads to 3,000 could, for example, cover a broad range of targets, as the medium set of targets in Table 1 on page 14 illustrates. This set of targets still includes a large portion of the Soviet conventional military infrastructure, as well as major war-supporting and military industrial sites. In addition, the medium set includes many key counterforce targets such as missile launch control centers, as well as a number of leadership sites, all of which the Soviet leadership presumably holds dear. But it is not big enough to include all Soviet missile silos or a large fraction of Soviet presurveyed mobile missile launch points and other counterforce targets. For comparison, the large set of targets in Table 1 illustrates the type of coverage current U.S. forces could provide assuming these weapons were not launched on warning of a Soviet attack.

Thus, nuclear forces of the size of Option III would not leave the United States in a situation of being able to retaliate only against Soviet cities or the Soviet population after absorbing a first-strike attack. If one believes that deterrence requires that U.S. second-strike forces be able to destroy a sizable fraction of Soviet targets in each category, but does not require targeting mobile missiles or every missile silo, a medium nuclear force such as the one outlined in Option III could be sufficient.

An option that reduced warheads to 1,000 would not be able to provide the same second-strike target coverage as current forces or a 3,000-warhead force, although it could still cover a broad range of targets. (The small set of targets in Table 1 illustrates one possible allocation of these small forces.)

This small set of targets, as illustrated, would forgo all counterforce and command, control, communications, and intelligence targets, but it would provide nearly the same level of coverage of other military and industrial targets as would the medium set of targets. As noted earlier, forgoing counterforce targets would reflect the beliefs of some military analysts who question the efficacy and desirability of counterforce targeting. In their view, not only does the destructive power of nuclear weapons make the implicit threat of societal destruction a more compelling deterrent than the destruction of missile silos, but targeting mobile platforms such as mobile missiles, bombers, and submarines tends to drive up requirements for warheads without increasing security, and may even degrade security.

Although most advocates of small arsenals assume that the United States would forgo counterforce targeting, nothing is inherent in either the forces or the number of surviving warheads that would preclude targeting assets in any of the four target categories. For example, given the modern force outlined in Option IV, the United States would still have the flexibility to target any combination of targets in all four categories with its surviving warheads, including key C^{3}I and counterforce assets.

In sum, during a retaliatory strike, small nuclear forces such as those proposed in Option IV could cover significant portions of one or two categories--for example, other military targets or industrial targets--or cover a range of targets in all four categories. Doing so would enable the United States to avoid targeting population centers directly during a second strike, although it would have to choose its targets carefully to ensure that they were not near population centers. If one believes that to provide an adequate deterrent, the U.S. second-strike forces must be able to destroy major industrial and conventional military targets, or important C^3I nodes, small nuclear forces such as those proposed in Option IV could be sufficient.

Limitations of This Analysis

The preceding analysis makes it clear that, even at lower levels of warheads, the United States could cover a substantial number of key Soviet targets and would not have to rely on city-busting for deterrence. One should be careful, however, in using this analysis to draw specific conclusions about the capabilities of U.S. second-strike forces for several reasons.

These illustrative sets of targets have been constructed without detailed knowledge of U.S. war plans, which are highly classified. In the event of a war, U.S. planners may prefer to execute a different type of war plan, possibly emphasizing counterforce targets over C^3I targets, or targets in the other military category over those in the industrial category. U.S. target planners also may design sets of targets to minimize the collateral damage to the Soviet Union during the second strike. In addition, the Soviet Union cannot discount the possibility that the United States would launch its missiles on warning of attack, which would substantially increase the number of targets that could be covered in a second strike.

Moreover, the United States would be likely to hold back some of its surviving warheads from a second strike in order to have a so-called strategic reserve to deter the Soviet Union or another nuclear power from further attacks on the United States. Without knowing the U.S. plans for the strategic reserve, the number of surviving warheads available for a second strike would be uncertain.

Also, the illustrative sets of targets used in the analysis represent actual objects (targets) that would have to be destroyed and not the number of warheads that would be necessary to destroy those targets. Some targets that are hardened against nuclear attacks, such as missile silos or C3I facilities, might require more than one warhead per target to assure a sufficient probability of damage. However, some softer targets will be located close enough to each other (collocated) that a single warhead could destroy several of them. Without access to detailed intelligence data, no one can tell how many targets would be collocated, or how many might need more than one warhead. Today, however, reports suggest that there are about 50 percent more warheads in U.S. war plans than targets for these warheads to attack.

In addition, the analysis in this section assumes that the U.S. command and control system for fighting a nuclear war could execute the second strike. The Soviet Union might very well target the U.S. C3I network to degrade the United States' ability to retaliate. But this study assumes that this network, with its many redundant systems, would function well enough to launch a second strike. This assumption is critical because, if the U.S. C3I system were inadequate, many of the warheads that survived the first strike would not get the order to launch, or could not be launched in an efficient, coordinated manner.

EFFECTS OF DEFENSES

So far, this chapter has focused on U.S. and Soviet capabilities assuming that defenses have not been deployed. What effects would a system of U.S. defenses have on the results? Calculating the effects of defenses on deterrence and the strategic balance is difficult because the effectiveness of one country's defenses depends on the reaction of the other country.

Large-Scale Defenses

The United States has proposed to deploy a large-scale system of defenses against ballistic missiles. Initially, that system would consist of the Global Protection Against Limited Strikes system, designed to intercept 100 to 200 incoming warheads. Later, the United States intends to deploy Phase I of a larger system designed to intercept at least 1,500 incoming warheads. Although the effectiveness of these systems has not yet been proven, this study assumes that they would perform as advertised. These numbers are very rough, however, because they depend heavily on assumptions about the presence of decoys and countermeasures, the number of warheads carried by each missile, the duration of the missile boost phase, and other factors.

Under some scenarios, it is theoretically possible that deploying such a system could have favorable effects on the U.S. ability to deter nuclear war. Even if the United States deployed a large-scale system, the Soviet Union might decide not to deploy a system of its own and not to institute measures to counter U.S. defenses. The Soviet Union might also elect to abide by limits on offensive systems such as those in the START treaty. Under these assumptions, the U.S. system of defenses would reduce the number of warheads arriving in the United States during a hypothetical Soviet first strike and, hence, increase the number of surviving U.S. warheads. Thus, the United States would have greater second-strike capability and, presumably, greater ability to deter a Soviet attack. Alternatively, the United States could reduce the size of its offensive arsenal and still achieve the same second-strike deterrent that it had before defenses were deployed.

Another scenario, perhaps even more favorable to the United States and the world, assumes that the Soviet Union would respond to the U.S. deployment of large-scale defenses by deploying a system of its own with similar capabilities. Such a deployment could lead to a stable situation in which both sides are deterred from starting a nuclear war because they know the potential opponent has effective defenses. Deterrence based on effective defenses rather than on the threat of annihilation through offensive forces is appealing, although it would require fundamental transformations in the military doctrines of both sides. It may have been this hope that led President Reagan to propose the Strategic Defense Initiative in 1983.

Unfortunately, other Soviet reactions to large-scale U.S. defenses could lead to results that are unfavorable to the United States. From the Soviet perspective, U.S. defenses might create the possibility that the United States could effectively disarm the Soviet Union in a first-strike attack.

Assume, for example, that under START the United States had deployed a Phase I defense. Theoretically, were the United States to mount a first-strike attack before the Soviet Union had placed its forces on alert, the Soviet Union could be left with fewer than 1,000 warheads after such an attack. Since all of these warheads are on ballistic missiles--Soviet bombers are destroyed on the ground in this surprise-attack scenario--and since Phase I of the U.S. system of defenses is advertised to be able to destroy at least 1,500 warheads, the United States could effectively nullify the Soviet second-strike force and hence Soviet confidence in its ability to deter war.

To counter this situation, the Soviet Union might adopt an explicit launch-on-warning doctrine, whereby it would plan to launch its missiles as soon as its electronic sensors were thought to have detected a nuclear launch by the United States. Because of the short time that the Soviet leaders would have to make a decision to launch, this factor would increase the danger of accidental nuclear war during a crisis. Under these assumptions, U.S. defenses and Soviet reactions could lead to greater instability in a crisis.

This scenario illustrates an important result: a defense that is large enough to intercept a significant fraction of an opponent's first-strike force is also large enough to degrade seriously that opponent's second-strike capability. If deterrence is based on the threat of retaliation--as it is today--this scenario could undermine deterrence. The side deploying the large defense would not necessarily intend to strike first, but the perception that it could gain an advantage by doing so might well spur the opponent to react.

Soviet leaders could also react in other ways. They might, for example, improve the day-to-day survivability of their nuclear forces by placing more bombers on runway alert and deploying more submarines at sea. More ominously, they could use the supreme national interest clause in the START treaty to end their adherence to the treaty and to increase the size of their offensive arsenal. Soviet leaders have stated they might take this step if the United States deploys defenses. They could also deploy countermeasures (such as fast-burn boosters and decoys) on their offensive forces that would enable more of these forces to penetrate the space- and land-based layers of U.S. defenses. Finally, the Soviet Union could deploy an antisatellite system designed to attack the space-based portion of the U.S. defense system.

Some combination of these measures would improve the Soviet second-strike capability by eroding the effectiveness of U.S. defenses. The United States might then improve its defenses in response to Soviet countermeasures, and the Soviet Union might respond to the U.S. improvements. The cycle could continue on and on, increasing costs without necessarily increasing security.

Nor would the outcome necessarily be favorable to the United States if, instead of countermeasures, the Soviet Union deploys its own large-scale system of defenses. Strong defenses on both sides could lead to deterrence through defense rather than the threat of nuclear destruction. But such a scenario might not unfold for several reasons. First, the weapons that make up space-based defenses would make excellent weapons against other space-based defenses. An aggressor could use these weapons to destroy an opponent's defenses as part of a first strike, thus reintroducing the possibility of a disarming first-strike attack. Second, without bilateral limits on defenses, each side might feel compelled to develop countermeasures. This situation could erode confidence in the ability to deter through defenses and increase the value of offensive forces for deterrence.

In sum, the effects of large-scale U.S. defenses would depend on Soviet responses. In some circumstances, defenses could improve U.S. ability to deter war and might even lead to deterrence based on effective defenses rather than on the threat of annihilation. These outcomes would add to any benefits the START treaty provided. Under other circumstances, however, Soviet responses to large-scale U.S. defenses could lead to less stability in a crisis, abrogation of offensive arms limits, and an escalating arms race.

Limited Defenses

Limited defenses such as the Administration's proposed GPALS or the smaller versions of GPALS analyzed in this study offer some advantages but pose fewer risks than large-scale defenses. Limited defenses could protect the United States against an accidental or unintentional

launch by the Soviet Union or against the forces of a hostile country that developed a modest long-range ballistic missile capability at some point in the future. Yet, a U.S. system of limited capability would not be large enough to prevent Soviet retaliation, and hence would not create the problems discussed earlier.

To ensure that defenses remained limited, the number of interceptors and sensors could be restricted roughly in proportion to the size of the arsenal allowed by arms agreements, which is the approach assumed in this study. For example, the permitted defensive capability might be based on the size of a possible launch by a single ballistic missile submarine or ICBM field. This approach should provide adequate protection against an accidental launch or one authorized by a rogue commander. Under arms agreements that resulted in fewer warheads per missile, the permitted size of defensive systems could decrease.

Limited defenses are not without their drawbacks. These defenses would not provide the degree of protection against an accidental launch offered by large-scale defenses. Also, without negotiated limits on these defenses, an opponent might have difficulty determining the capabilities of a limited defense. It might also have to worry about defensive breakout and therefore might resist deeper cuts in offensive forces than it would otherwise. Finally, the limited defenses that the Administration has proposed, and all those analyzed in the options considered in this study, would violate the existing ABM treaty (and the 1974 Protocol to the 1972 treaty) because they deploy either space-based interceptors, too many ground-based interceptors, too many radar systems, or ground-based interceptors at too many sites. Without the treaty, an arms race in defensive systems could develop, perhaps adding much to budgets but little to security.

IMPROVING THE SAFETY OF ALL POSTURES

Although most of this chapter highlights the differences between options, certain types of additional accords between the superpowers might buttress any one of the force postures and arms control programs outlined here. Rather than focus on quantitative arms control, these accords could continue the longstanding superpower process of improving communications, reliability, and safeguards. These agreements might not all be directly verifiable, but they might be useful nonetheless, and military consultations between the superpowers might expedite them.

For example, both countries could ensure that permissive action links (PALs) protect all of their warheads, which would make weapons inoperable unless activated by special codes. They also could place self-destruct mechanisms on all their ballistic missiles (just as they now do with flight-test missiles) to counter an accidental or unauthorized launch. Reportedly, such mechanisms can be made highly impervious to espionage or sabotage and thus would not weaken deterrence.[5]

The United States and the Soviet Union also could agree to move away from their launch-on-warning postures, and could even reduce the alert levels of their missile systems during normal conditions.[6] Doing so would be more feasible under an arms agreement that limited the degree to which multiple warheads (MIRVs) could be placed on missiles, while allowing a variety of strategic launcher systems to provide weapons survivability.

If under attack, leaders still might delegate positive control of nuclear forces to commanders in the field since in all likelihood command, control, and communications systems would remain highly vulnerable under any option. But they could eschew an actual launch of weapons until certain that the other side had indeed launched a nuclear strike, in contrast to the current situation in which launch on warning appears to be a real policy option.

This approach would retain retaliatory forces able to survive, and would reduce the risks of a false alarm leading to inadvertent nuclear war. The policy might be helped by further improvements on both sides--perhaps studied and developed jointly--to ensure that C3I could

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5. See, for example, International Foundation for the Survival and Development of Humanity, *Reducing the Dangers of Accidental and Unauthorized Nuclear Launch and Terrorist Attack: Alternatives to a Ballistic Missile Defense System* (Washington, D.C., 1990), pp. 16-18.

6. International Foundation for the Survival and Development of Humanity, *Reducing the Dangers*, pp. 13-14; Bruce G. Blair and Henry W. Kendall, "Accidental Nuclear War," *Scientific American* (December 1990), pp. 53-58.

remain survivable and reconstitutable, largely through enhanced use of mobile and redundant systems and through sharing of some early warning systems.

CHAPTER VI

VERIFICATION

The post-START reductions in nuclear forces discussed in the preceding chapters, when codified by a bilateral treaty, might provide substantial retaliatory capability while also saving money. However, could the United States monitor the behavior of the Soviet Union so as to be confident that Moscow was complying with a new and far-reaching treaty, as well as any unilateral pledges it had made to reduce its own forces? If the Soviet Union chose to violate a treaty or its own pledges blatantly--an unlikely possibility, but one that must be addressed--could U.S. security be put in jeopardy?

This chapter addresses issues of verification, Soviet compliance or noncompliance with a post-START treaty, and the corresponding implications for U.S. security. No verification procedures can ever be perfectly effective, and noncompliance cannot be ruled out under any arms control regime. Thus, CBO cannot conclude that either the proposed START treaty or the post-START options would clearly be verifiable, since that conclusion depends on a judgment about how much uncertainty is an acceptable price to pay for the benefits of arms control.

One conclusion does seem clear, however: the direct military risks of any Soviet cheating probably would be modest, primarily because of the mobility of many U.S. systems. Submarines could avoid detection and attack when dispersed, and alert bombers generally could take off from runways before the attacking warheads would arrive.

CURRENT CAPABILITIES FOR VERIFICATION

Verification is really a subset of a much broader function called intelligence, which estimates the capabilities and characteristics of various countries in economic, political, and military realms. Actually, the use of the word verification can be misleading, since it presupposes that compliance is taking place and also implies a degree of certitude. More accurately, if more cumbersomely, one should say that a state accumulates data on the forces of other states through various monitoring methods, and then analyzes that data to reach assessments about the compliance or noncompliance of other states.

Some history of the late 1970s and early 1980s offers concrete and vivid examples of the distinction between these terms. During this period, information that the United States obtained by monitoring a number of Soviet activities was used to determine that the Soviet Union was not complying with all of its commitments under several treaties. In particular, the Soviet Union was accused of building the Krasnoyarsk radar in a location not permitted by the Anti-Ballistic Missile Treaty, using air-defense radar systems during testing of ballistic missile defenses (also prohibited by the ABM treaty), building one more new type of ICBM than was allowable under SALT II, and encoding missile telemetry.

For these assessments of compliance to have been made, U.S. reconnaissance and verification systems must have been quite capable. In most cases, improving U.S. verification would have made little or no difference; the problems were not in U.S. monitoring capabilities, but in the Soviet Union's behavior and in disagreements between the two countries over treaty interpretations.

Hence, much of the debate over whether U.S. reconnaissance systems should be capable of "adequate" verification, or a more demanding "effective" verification, may miss the main point--that even high-quality reconnaissance systems cannot force other countries to behave in a certain fashion. But they clearly have a critical role in providing timely notice of violations that could permit various types of demarches or military responses, not to mention deterring those violations in the first place.

Since the development of satellite technology, it has been possible to count large military systems and large fixed sites--missile silos, submarine bases and the submarines themselves when they are in port, bomber airfields and the bombers themselves when on the ground, large radar systems, surface ships, and so forth. Moreover, it has been possible to do so very accurately, assuming one knows the general area in which to search for them. Large buildings are also easily spotted--provided that the areas in which they are located are surveyed--though problems can arise in determining which buildings perform what functions. Sometimes certain parts of a country are ignored over long periods, leaving major facilities undetected, as in the case of the huge Krasnoyarsk radar system in central Siberia. But such situations have been unusual.

Moreover, recent increases in the number of imaging satellites, together with the advent of cloud-penetrating radar satellites, have made it easier to survey remote regions than in the past. In general, arms control treaties have been able to specify numerical or geographical restrictions on such systems with precision--especially in the cases of submarines, missile silos, and large fixed radars--with the expectation that compliance with exact limits could be precisely verified.[1]

How do imaging satellites survey the Earth? Their operations have been likened to looking at a distant and detailed object through a long and narrow straw. Although much could be imaged at any given time, only a very small fraction of the total field of view actually can be examined in detail. Indeed, as a satellite's resolution improves, this problem is exacerbated, since adjacent imaging units or "pixels" each correspond to smaller and smaller regions on the ground.

To take some specific examples, SPOT commercial imaging satellites, in orbit at about 800 kilometers, take photographs with resolutions of about 10 meters that cover about 10 km on a dimension. From altitudes as low as 200 km, the U.S. KH-11 imaging satellite reportedly can resolve features as small as 15 centimeters on a side. For normal scanning, and for treaty verification, however, it may not need such good resolution. Assuming that it can adjust its resolution and that most START objects can be identified with a resolution of perhaps

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[1] See Paul B. Stares, *Space and National Security* (Washington, D.C.: Brookings Institution, 1987); Congressional Budget Office, *U.S. Costs of Verification and Compliance Under Pending Arms Treaties* (1990); Bruce D. Berkowitz and Allan E. Goodman, *Strategic Intelligence for American National Security* (Princeton: Princeton University Press, 1989); Jeffrey T. Richelson, *The U.S. Intelligence Community* (Cambridge: Ballinger, 1989); Jeffrey T. Richelson, *America's Secret Eyes in Space* (New York: Harper and Row Publishers, 1990); William E. Burrows, *Deep Black* (New York: Random House, 1986).

2 meters, a KH-11 operating with this resolution would produce images covering about 1 km on a dimension (assuming that, as with the space telescope, a KH-11's sensor has about 800 pixels on a side).

Taking 100 images per day, a satellite thus might cover 100 km^2 of the Soviet Union--or less than .001 percent of the total 22,000,000 km^2 of the country. If the satellites can be used to monitor key areas, this amount of coverage can be sufficient. But for this to be possible, other intelligence sources must provide good information on where to look, or the satellites themselves must be adapted to conduct wide-area surveillance as well as high-resolution imaging.

The satellites would be overflying a great deal of land during a single day. With a visual horizon of about 2,500 km at an altitude of 500 km, and a horizontal shifting per orbit of 2,500 km because of the Earth's rotation, a given satellite probably can image any point on Earth at least once a day--if it can turn its telescope at least 60 degrees to either side of its axis of motion. But at any given moment, a satellite in orbit at 500 km can see only about 3 percent of the Earth's surface. To assure that all points on Earth could be within the satellite fleet's field of view continuously--even if only actually imaged occasionally--would require a constellation of perhaps 15 to 30 radar-imaging satellites in orbit at 500 to 1,000 km.

Whereas satellites can count large or fixed objects quite well, they cannot do quite as well with aircraft. Some aircraft can be inside shelters and thus hidden from view; others, though in view, might be in motion often enough to be confused with each other and thus not precisely counted. Larger aircraft such as strategic bombers are, however, difficult enough to hide, and generally few enough in number, that they can be counted reasonably well.

Estimates of total numbers of mobile radar systems, mobile missile launchers, and nondeployed missiles are less accurate. Arms control has only recently begun to limit these types of weapons, necessitating cooperative exchanges of data bases and on-site inspections as complements to traditional national technical means of reconnaissance and intelligence. Moreover, even when their numbers are known within a moderately narrow range of values, the locations of these systems at any one time often are not well known at all. But this state of affairs could be desirable for arms control and stability, since it means that verifying compliance with numerical ceilings in arms control agreements can be more precise than targeting for wartime operations.

In this regard, the exchange of data bases is extremely helpful, for it allows each individual inspection to constitute a check on compliance. Without such information, each side would have to develop its own estimates of the other side's inventories, and would be able to claim a violation only after consistently finding more equipment at each known military site than statistics suggested should be there.

Laboratory laser weapons and other research and development projects, factory production rates, very small systems such as cruise missiles, and nuclear warheads themselves are quite difficult to investigate with satellites. Nuclear warheads require special production facilities, but these facilities have operated without careful monitoring for so long that it is now hard to derive accurate estimates of what has been produced. At low numbers of allowable warheads, however, it may become necessary to find ways to limit warheads verifiably. To do this would probably require exchanges of data bases for all warheads and fissile materials, as well as on-site inspections including so-called challenge or suspect-site inspections.

If warhead inventories were to be slashed, it might also be desirable to devise an accord mandating verifiable destruction of existing warheads and dilution or irretrievable disposal of fissile materials. Exchanges of information on the stockpiles of such materials, as well as the production histories of various nuclear reactors and enrichment facilities, would also be helpful.[2] Limits on tritium production on both sides might also be a useful measure, given tritium's presence in most strategic warheads and its short half-life (12.3 years). These types of agreements could not be verified with great precision, given the uncertainties over how much material the superpowers have produced during the last five decades. But they could be a useful adjunct to limitations on delivery vehicles.

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[2] Frank N. von Hippel, "Warhead and Fissile-Material Declarations," in Frank N. von Hippel and Roald Z. Sagdeev, *Reversing the Arms Race* (New York: Gordon and Breach, 1990), p. 61; Harold A. Feiveson and Frank N. von Hippel, "Beyond START: How to Make Much Deeper Cuts," *International Security* (Summer 1990), pp. 154-180, especially p. 176.

Finally, deployed space-based systems probably can be monitored fairly well with the telescopes that both superpowers use for space tracking. It is likely, for example, that brilliant pebbles--the space-based interceptors that figure into the Administration's plans for strategic defenses--could be monitored fairly effectively by the Soviet Union once deployed individually. But production of systems such as brilliant pebbles probably could not be monitored as accurately. Research and development of these systems probably could be verified effectively only when involving tests in space.

NEW VERIFICATION TECHNIQUES AND THEIR CAPABILITIES

Systems for verifying nuclear arms control treaties of the types treated here probably would include expanded versions of the techniques currently being developed and carried out for the International Atomic Energy Agency (IAEA) and for the Intermediate-Range Nuclear Forces, Strategic Arms Reduction Talks, Conventional Forces in Europe (CFE), and the nuclear test ban treaties. Thus, they would continue to ensure unimpeded use of national technical means; they would also include exchanges of data bases together with various types of on-site inspections at military bases and suspect sites, as well as portal monitoring of some production facilities.

For the more ambitious treaties sketched out above--in particular, those that reduce strategic warheads to 3,000 or 1,000--further measures might be required. A key example is in the area of surplus missiles. START would limit extra mobile missiles, but not other nondeployed missile inventories. They may have to be constrained and monitored under an ambitious weapons reduction scheme, however. CBO assumes that all launchers and warheads would be countable under all four options for post-START arms control. It might also be desirable for all new missiles to have only one warhead and a small payload. Such measures would reduce the danger of rapid treaty breakout.

In some cases--particularly under the options that leave 6,000 or more warheads--it might be sufficient to require both countries to make politically binding declarations that they would not exceed certain ceilings for nondeployed weapons. For options involving deep cuts in warheads, however, such declarations might not be sufficient. Current inventories of nondeployed weapons exceed the deployable force levels that would be allowable under these options, and thus could hardly be considered secondary or insignificant. Verifying destruction of excess equipment and instituting specially tailored monitoring procedures for these systems would be important. Doing so could entail more normal quota inspections and more challenge inspections, together with exchanges of data bases to make such inspections fruitful.

Such a broadening of the scope of arms control would affect several types of systems in new ways. Presumably, factories and storage depots would need to be listed on data bases and subject to inspection. Since conventional sea-launched cruise missiles probably would remain in both countries' arsenals, there would need to be a means of verifying that they were nonnuclear. Passive or active radiation detectors might be necessary during quota inspections for this purpose, as well as tags and seals installed on missiles at factories in order to prevent warheads from being clandestinely swapped in the field. Missile factories and assembly sites might need to be either included in data bases or inspectable during challenge inspections, since parts of them could in theory be used as large warehouses for surplus missiles.

Unless a high degree of confidence was placed in the challenge inspection system, production sites for various types of missiles might require what is known as continuous portal-perimeter monitoring--in which fences are built around plants, and exits and entrances are constantly surveyed--under these new measures. In this event, tags placed on missiles could be used to prevent clandestinely produced missiles from being tested at test sites, where inspectors would also be located. Tests at other sites would be prohibited and could be detected quite easily, were they to take place in violation of treaty strictures.

In an arms control program in which arsenals were sharply reduced, warhead limits would be helpful components of a robust treaty and verification process. Without them, even if systems such as con-

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ventional aircraft and conventional SLCMs could be verifiably monitored under normal circumstances, the possibility of sudden breakout would remain. Neither side could be confident that such systems could not be quickly reconfigured to carry nuclear warheads, though doing so might require returning these systems to factories for conversion.

A number of U.S. and Soviet scientists have recently developed and analyzed a comprehensive method for estimating existing quantities of fissile materials and warheads, and for monitoring future inventories. At the outset, an agreement to cease all production of plutonium and highly enriched uranium for nuclear weapons would have to take place. Other features would include monitoring the destruction of warheads, monitoring the disposal of usable fissile materials, making cooperative measurements of certain parts of countries' nuclear production reactors to gauge past production from radioactive residuals, and placing safeguards on those reactors allowed to continue in operation for tritium production and for production of materials for naval propulsion.

Some of these procedures would be complicated, since the United States and the Soviet Union consider the design and the fissile contents of most warheads as highly classified information. Thus, several types of warheads might have to be destroyed together in groups so that their total fissile content (presumably an unclassified number) could be measured even though the composition of individual warheads could not be. The highly enriched uranium and plutonium would be used as reactor fuel, safeguarded, or mixed with highly radioactive waste products and buried.[3]

According to some estimates, these procedures taken together could make it possible to put an upper bound on the possible total size of any hidden stockpiles. This limit would be on the order of several thousand warheads.

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[3] Theodore B. Taylor, "Warhead Dismantlement and Fissile-Material Disposal," in von Hippel and Sagdeev, *Reversing the Arms Race*.

EXAMPLES OF VERIFICATION TECHNIQUES FOR POST-START OPTIONS

All of the aforementioned verification techniques can be organized into five separate tiers of monitoring capability.

The first tier involves national technical means--imaging and signals intelligence satellites, ground-based radar systems, seismic-monitoring stations, and aircraft. For deployed strategic launchers together with mobile missile reloads, the second tier involves exchanges of data bases and on-site inspections--including challenge inspections, continuous portal-perimeter monitoring, and warhead-loading inspections for ballistic missiles carrying multiple warheads (MIRVs). The first tier thus corresponds to SALT-era verification techniques; the first and second together are equivalent to START techniques. These two tiers would probably be sufficient for the option in this study that bans heavy missiles and limits defensive systems but does not reduce warhead levels below those anticipated under the START treaty.

Depending on the degree of confidence desired for verifying reductions of tactical weapons, the two tiers might be acceptable as well for the option that would reduce strategic warheads to 6,000 (one-third below the START level). The assumption here, however, is that this option would entail a third tier of verification that focused on sea-launched cruise missiles and medium-range aircraft--two systems that have been peripherally included in the context of strategic arms negotiations already.

Further verification provisions on shorter-range systems might not, however, be considered necessary at this level. The superpowers' past willingness to ignore most theater systems in arms control negotiations suggests that they might be content simply to extend the concept of politically binding and unverified warhead limitations to all theater systems under this option.

Were options involving deeper cuts carried out, however, two additional tiers of verification techniques might be necessary. One would involve monitoring deployed and nondeployed missiles of all types; the other would involve monitoring total quantities of warheads and fissile materials. With deployed systems numbering 3,000 or 1,000 strategic warheads, current inventories of known excess missiles and warheads would be highly significant, at least politically.

COSTS OF VERIFICATION

The types of compliance-related activities and monitoring put forward here are likely to be comparable in cost with similar activities under INF, START, and IAEA. Thus, with a new accord in place, total arms control costs could double from the INF/START/IAEA annual level of about $500 million to about $1 billion per year.[4]

For any given inspection program associated with a new treaty, the number of annual quota inspections is assumed to be 10 percent to 30 percent of the number of sites listed in the data bases, and the number of challenge inspections each year to be about 25 percent to 50 percent as numerous as normal quota inspections. These numbers are derived by a comparison with CFE, INF, and START. CBO further assumes that all destruction and conversion activities would be monitored and that all allowable reactors capable of producing fissile material would be safeguarded. To perform costing calculations, these estimated numbers must be combined with the unit costs applicable to inspections under INF and the IAEA, and those thought likely for CFE, START, the nuclear test ban treaties, and the Chemical Weapons Agreement.

Note that some of the destruction and disposal costs listed in this category might have to be incurred eventually for environmental and safety reasons, even without arms control. Thus, one should interpret the costs shown here as possibly higher than costs specifically associated with treaties.

Somewhat greater costs than these could, however, be incurred in destroying and converting equipment, a process that is not yet fully understood. Most notably, costs could escalate as a consequence of the need to destroy missile equipment. Moreover, should continuous portal-perimeter monitoring be employed at as many as 10 sites in each country, annual recurring costs for this category of activity alone could approach $500 million. Inspection costs also could grow considerably if a great many inspections were made at highly sensitive facilities. But even under pessimistic assumptions, compliance and monitoring costs associated directly with treaties are almost certain not to attain the level of 1 percent of total defense spending.

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[4] Congressional Budget Office, *U.S. Costs of Verification and Compliance Under Pending Arms Treaties* (1990), chapters I and II.

THE IMPLICATIONS OF A POSSIBLE SOVIET BREAKOUT FOR U.S. SECURITY AND FOR STABILITY

With the multiple layers or tiers of monitoring discussed above, any large-scale Soviet violation of a future arms control accord is unlikely to go undetected very long. However, monitoring cannot prevent noncompliance; all it can do is detect hypothetical violations in a timely manner. Thus, investigating the impact on U.S. security of a plausible, large Soviet violation is extremely important.

Were the superpowers to agree to an arms control accord allowing only 1,000 nuclear warheads on each side, a well-disguised policy of noncompliance by one country could produce an illicit arsenal bigger than the allowed arsenal. For example, 4,000 excess warheads, together with delivery vehicles for all of them, could possibly be developed, resulting in a total Soviet nuclear arsenal of 5,000 warheads.[5]

These excess forces, if stored or produced clandestinely, would be highly unlikely to involve new submarines or dedicated strategic bombers. Such weapons platforms are too easily spotted by satellite or other means. Much more likely is that mobile launchers might be deployed with excess land-based missiles equipped to deliver excess warheads, that downloaded SLBMs might be rapidly reconfigured with their full potential complement of warheads, or that ships and tactical aircraft might be reconfigured to carry nuclear munitions.

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[5] The uncertainty in current U.S. estimates of Soviet fissile materials, warheads, and missiles is of this magnitude. See Allan Krass, *The Verification Revolution* (Cambridge: Union of Concerned Scientists, 1989), pp. 26-27. (Krass points out that during Intermediate-Range Nuclear Forces Treaty negotiations, published U.S. intelligence estimates of Soviet nondeployed SS-20s varied from 100 to 750; the number finally accepted was the Soviet number, 245.) See also Bill Gertz, "U.S. Fails to Count Half of Soviet Arms," *Washington Times*, February 5, 1990, p. 5; von Hippel, "Warhead and Fissile-Material Declarations," p. 77; Taylor, "Warhead Dismantlement and Fissile-Material Disposal," pp. 92-93.

Thus, by way of illustration, consider two cases. The first assumes that the illicit warheads are deployed on counterforce platforms--3,000 on accurate land-based ICBMs, and 1,000 on previously downloaded SLBMs too inaccurate to be used against hard targets but effective in antibomber barrage attacks. The second case assumes that the excess warheads are deployed on a variety of platforms suitable for tactical missions--either for war at sea or combined air-ground operations in a limited geographic theater.

A third type of calculation, not performed here, could assume a breakout of defensive systems. Neither superpower appears to have the technological capacity to produce highly effective defenses today, so this concern remains largely theoretical. But were defenses to become technologically feasible, a defense breakout by either side could be a worrisome scenario.

The Soviet breakout force with 3,000 extra ICBM warheads and 1,000 extra SLBM warheads would not reduce the survivability of the U.S. submarine forces at all. All deployed submarines would remain invulnerable, and all submarines in port would be destroyed with or without the assumption of breakout. The number of warheads available to the Soviet Union would not begin to be sufficient to barrage submarine deployment areas. For example, the deployment zones for Ohio-class submarines cover tens of millions of square kilometers of ocean, and a single warhead can destroy submarines only within an area of about 50 to 100 km^2. Carrying out an effective barrage would therefore require hundreds of thousands of warheads.

The SLBM breakout force would provide the Soviet Union with a much larger warhead inventory with which to barrage U.S. bombers. Under day-to-day conditions, no U.S. bombers would be on alert, and therefore no bombers would survive under either the 1,000-warhead or the breakout scenario. Based on the models described in Appendix B, during a generated alert, the breakout force could destroy only five more bombers than the 1,000-warhead force that complied with Option IV.

The situation for U.S. silo-based ICBMs is somewhat more complex. In all likelihood, no more than two warheads could attack silo-based ICBMs before incoming warheads would destroy each other in a process, described in Chapter V, known as fratricide. Since the Soviet Union already would have nearly enough warheads for two-on-one attacks with its assumed 1,000-warhead force, the addition of 3,000 ICBM warheads would probably affect the survivability of silos only slightly.

The Soviet Union could, however, attempt to employ a technique known as pindown to attack silo-based ICBMs with multiple waves of warheads. The technique is quite complicated and cannot be tested. But if successfully executed, it could reduce the survivability of silo-based ICBMs.

With this tactic, the Soviet Union would target silos in a two-on-one scheme at first. At about the same time, it would begin detonating warheads in ICBM escape corridors above the atmosphere. (ICBMs based in a given silo field would, upon launch, all pass through a relatively small volume of space as they left the atmosphere en route to an intercontinental destination; this small volume is sometimes referred to as an escape corridor.) Older warheads might be countered by any nuclear burst within tens of kilometers of them in outer space; against such warheads it might be sufficient to use only a few detonations per minute to prevent ICBMs from being able to embark safely. Against more hardened ICBMs such as the MX, however, the destruction radius of nuclear bursts outside the atmosphere could be reduced by an order of magnitude, requiring an attacker to use hundreds of megatons of explosions per minute in the escape corridors.[6]

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[6] These numbers are rough estimates based on information in Richard L. Garwin and Hans A. Bethe, "Anti-Ballistic-Missile Systems," *Scientific American* (March 1968), p. 27; and Matthew Bunn and Kosta Tsipis, "Ballistic Missile Guidance and Technical Uncertainties of Countersilo Attacks," Report Number 9, Program in Science and Technology for International Security, Department of Physics, Massachusetts Institute of Technology (August 1983), p. 79.

Eventually, the debris produced by the first warheads targeted on silos would settle, enabling successive waves of silo-destroying warheads to be launched before the silo-based ICBMs could escape. If it were necessary to prevent ICBMs from departing for one hour, for example, several hundred Soviet warheads would be required to counter older U.S. systems, and tens of thousands to counter modern systems. Thus, a Soviet breakout might pose a risk to older silo-based U.S. ICBMs, at least theoretically. But these ICBMs would not be highly survivable anyway, if the Soviet Union did not cheat. Furthermore, the Soviet Union would still have to contend with the hundreds of warheads deployed on U.S. ballistic missile submarines.

In a scenario in which a tactical-weapons breakout took place, the U.S. nuclear deterrent would not be threatened, but its conventional military forces might be. For example, the Soviet Union could deploy hundreds or thousands of nuclear warheads on sea-launched and bomber-launched cruise missiles, and attack U.S. naval vessels en route to Europe. Alternatively, it could deploy warheads with its artillery brigades to produce large holes in NATO combat forces in a European engagement.

The possible military utility of nuclear weapons in such roles cannot be ruled out in this scenario, just as it cannot be ruled out today. But the United States would retain the option of targeting several hundred Soviet assets in reprisal. In reality, therefore, the situation might not be fundamentally different from a situation in which both countries were in compliance. In either situation, one can imagine scenarios in which one side theoretically could gain an advantage by using its nuclear weapons first against a certain set of targets. The risks of Soviet advantage could increase slightly under breakout. But ultimately, given the nature of nuclear weapons and nuclear deterrence, the exact details of the correlation of nuclear forces may not be appropriate.

A final concern is not a numerical breakout but a technological breakthrough that would fundamentally change the nature of the interaction between attacking and attacked forces. Sensor technologies that made submarines easier to locate, for example, could make the number of Soviet warheads highly relevant. In particular, determining the approximate location of a given number of such platforms could make barrage attacks feasible against the general areas known to be holding them. This concern, though hypothetical, is legitimate, and remains a good argument in favor of diversity in the strategic deterrent force. For this reason, all the options treated in this study involve several different types of launchers and large numbers of mobile platforms.

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CHAPTER VII

NUCLEAR FORCES AND INTERNATIONAL POLITICS

Up to this point, the analysis has focused on the effects that the Administration's plan and the various options would have on the balance of U.S. and Soviet nuclear forces. But nuclear forces have broad military and political effects. To some extent, potent nuclear forces may be necessary to maintain superpower status--which in turn may help the United States play a stabilizing and responsible role in much of its military policy and overall foreign policy. But these facts beg a number of questions. Would deep reductions in nuclear forces jeopardize the status of the United States as a superpower? How would options that led to deep cuts in strategic forces influence the ability of the United States to achieve other desirable goals, such as halting the spread of nuclear weapons to other countries? How would these options affect the capacity of the United States to deter attacks against its overseas allies--what is sometimes referred to as U.S. extended deterrence?

Similar questions apply, of course, to the Soviet Union or its successor state. Although it is not the purpose of this study to evaluate the desirability of sweeping arms control as seen from the Kremlin, it may nevertheless be useful to gain some sense of whether or not deep nuclear cuts would be negotiable from the perspective of the Soviet Union.

THE EFFECT OF THE OPTIONS ON U.S. SUPERPOWER STATUS

Would major cuts in the U.S. nuclear posture change the political landscape so much as to call into question U.S. superpower status, thereby perhaps emboldening other countries to be more aggressive internationally? Even in the option that reduces warheads to 1,000, the United States would retain more warheads than any country other than the Soviet Union. The United States would have more warheads than Britain, France, and the People's Republic of China, which are estimated to have 700, 500, and 300 nuclear warheads, respectively.[1] Nevertheless, the effects of deep U.S. reductions on its superpower status are of concern, especially reductions that would leave the United States with 1,000 warheads.

One way to deal with concern over the holdings of these medium nuclear powers would be to accompany or follow superpower arms cuts by an agreement among the five permanent members of the United Nations Security Council not to exceed their current respective levels of warheads. This pact would have the effect of limiting British, French, and Chinese nuclear forces, and protecting the numerical advantage, and hence the nuclear superpower status, of the United States. A realistic prospect for such an agreement might exist because it would not require the medium nuclear powers to carry out actual reductions in their arsenals, only to limit their future size.

Even if the medium powers agreed not to exceed their current warhead holdings, an important military concern would remain: in thinking through a hypothetical nuclear war, one must consider how many warheads the superpowers would need to retain after attacking each other in order to deter the medium powers. This concern must be seen in perspective: since such an exchange would thoroughly decimate both societies, they would be unlikely to be particularly concerned afterward about global power balances. Nevertheless, some planners may see the issue as important, and they may therefore wish to keep a strategic reserve of perhaps tens or hundreds of warheads in order to retain some backbone of deterrence against one or more medium nuclear powers and other countries. For those individuals concerned about this scenario, the minimum requirements for global deterrence may be higher than for others who do not view it as a serious concern. Naturally, this concern may be greater for the Soviet Union than for the United States, given that Chinese forces are probably best viewed as nonaligned, whereas British and French forces are likely to remain at least loosely allied with U.S. forces into the indefinite future.

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[1] See International Institute for Strategic Studies, *The Military Balance 1990-1991* (London: Brassey's, 1990), p. 219; Theodore B. Taylor, "Warhead Dismantlement and Fissile-Material Disposal," in Frank N. von Hippel and Roald Z. Sagdeev, *Reversing the Arms Race* (New York: Gordon and Breach, 1990), p. 93.

In addition to the five declared nuclear powers, a multilateral agreement on nuclear forces could include any other declared or suspected nuclear powers that might wish to pursue arms control--India, Pakistan, Israel, South Africa, and perhaps others. Alternatively, the agreement could be reached in the context of the Nuclear Non-Proliferation Treaty, up for renewal in 1995. Ceasing production of fissile materials for warheads might be added to such an agreement as well.[2]

The options in this study that would lead to deep reductions could also affect the political status of the Soviet Union. The Soviet Union has already lost some of its image as a superpower because of its deep economic and political problems. Some hard-liners in the Soviet Union thus might view a sharp cut in Soviet nuclear forces, even if accompanied by U.S. cuts, as confirming their country's decline.

The force postures considered in this study, however, would reduce the size and capability of the U.S. arsenal at the same time that they reduced Soviet capabilities, and save the equivalent of perhaps $10 billion to $20 billion per year--as much as several percent of Soviet gross domestic product--which could aid the faltering Soviet economy. Unlike the unilateral troop withdrawals from Eastern Europe and Afghanistan, as well as the Conventional Forces in Europe Treaty that required the Soviet Union to make larger cuts than those required of the United States, strategic arms agreements that focused on actual warhead inventories would require symmetric cuts in U.S. and Soviet forces. (It remains too soon to know if President Bush's September 1991 call for further talks on strategic forces would envision symmetric cuts in the same way that options in this study envision them.)

Second, in a society such as the Soviet Union characterized by widespread unrest, smaller and more centralized nuclear forces would be considerably safer than larger, widely dispersed forces. Under a treaty of the type that would reduce armaments to 1,000 or 3,000 strategic warheads, the Soviet Union could easily justify withdrawing nuclear forces from potentially troublesome regions where they might otherwise be confiscated under certain scenarios. Even though safeguards may exist against theft on most or all of these weapons, these added safety features are desirable. They can prevent the loss of fissile materials and warhead design secrets. It may have been much this type of thinking that was behind the President's September initiative on theater nuclear weapons and Gorbachev's October response to this initiative.

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[2] For a general discussion of nonproliferation issues, see Lewis A. Dunn, "The Emerging Nuclear Suppliers: Some Guidelines for Policy," and William C. Potter, "The Behavior of the Emerging Nuclear Suppliers: Sources and Policy Implications," in William C. Potter, *International Nuclear Trade and Nonproliferation* (Lexington, Mass.: D.C. Heath and Company, 1990); *Bulletin of the Atomic Scientists* (July/August 1990).

EFFECTS OF THE OPTIONS ON NUCLEAR NONPROLIFERATION

Strong reasons exist to believe that the greatest nuclear risks in the future will derive from developing nations and not from the Soviet Union. Indeed, during the last year, the United States decided to go to war based in part on a potential Iraqi nuclear threat. A major row has also taken place with a traditionally strong ally--Pakistan--over that country's nuclear programs. How would the options in this study that lead to deep reductions in nuclear weapons affect U.S. efforts to halt the spread of nuclear weapons?

Some analysts would argue that certain countries might have stronger incentives to acquire nuclear weapons if the United States reduced its arsenal and removed nuclear weapons from overseas bases. Nations like South Korea, Taiwan, and perhaps even Japan and Germany face neighbors that are potentially hostile and that have nuclear weapons. These nations depend on the United States for assistance in providing their security. If deep cuts in U.S. nuclear forces signaled a reduction in U.S. willingness to assist in providing security, these countries might be more likely to seek nuclear weapons of their own.

Quite conceivably, however, a United States that remained globally active with its conventional military forces and its political commitments would retain the backbone of deterrence irrespective of the exact size of its nuclear forces. To the extent that the United States needs a nuclear capability to checkmate that of other countries, moreover, the exact details of this capability may be much less important than the simple fact that it exists--and that it is equal to the Soviet capability.

What McGeorge Bundy, national security advisor under President Kennedy, has called the "tradition of non-use" may be strong and deep-rooted enough after nearly five decades without nuclear warfare to make most details of the U.S. nuclear arsenal unimportant. This tradition was most recently demonstrated by the unwillingness of the anti-Iraq coalition to contemplate seriously employing nuclear weapons during the Gulf War (though in Bundy's view, the coalition should have been even more clear about its unwillingness to use nuclear weapons).[3]

Thus, options that led to deep reductions in the U.S. inventory of nuclear weapons would not necessarily change the incentives of other countries to develop and maintain their own nuclear arsenals--especially if the United States took special pains to reemphasize its global commitments to allies, through military exercises and other means, as it reduced its nuclear forces. Indeed, rather than foster nuclear proliferation, major cuts in U.S. and Soviet nuclear arms might give at least a modest impetus to international efforts seeking to slow and reduce proliferation in other ways. Sweeping arms control would constitute a significant symbolic step toward stemming the international proliferation and multiplication of weapons of mass destruction, putting the superpowers in better accord with the letter and spirit of the Nuclear Non-Proliferation Treaty.

As the 1995 date for reconsideration of the Nuclear Non-Proliferation Treaty approaches, the United States is resisting pleas by the international community to consider curbs on testing and is taking only relatively modest steps to reduce its nuclear forces. Some analysts are concerned that this U.S. resistance could jeopardize the willingness of other states to extend the treaty beyond 1995. A major reduction in superpower arms might persuade other nations to continue to adhere to a policy of nonproliferation.

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[3] McGeorge Bundy, *Danger and Survival* (New York: Vintage Books, Random House, Inc., 1988), p. 586; McGeorge Bundy, "Nuclear Weapons and the Gulf," *Foreign Affairs* (Fall 1991), pp. 83-94.

This argument should not be oversold. Leaders such as President Hussein of Iraq and President Kim of North Korea may be little swayed by sentimental arguments about following the good example of benevolent superpowers in complying with the letter and spirit of the Nuclear Non-Proliferation Treaty. But there might be benefits to better compliance with the treaty nonetheless. For example, it might help U.S. efforts to pressure noncompliant states into different behavior. Under circumstances similar to those that arose recently in Iraq, international sanctions and even military action might be employed against proliferators, especially if they retained aggressive foreign policies and seemed to be preparing for military operations. The capacity of the United States to mobilize Security Council and international support for such sanctions might be enhanced, to the degree that the United States itself was seen as acting responsibly and as following a nuclear policy that was compliant with the Nuclear Non-Proliferation Treaty.

Bolstering efforts to stem proliferation is a very worthy enterprise. More fingers on the nuclear trigger are always cause for worry. In the Third World, where most proliferation is likely to occur, other factors are of great concern. Warning and command and control systems may not be adequate to ensure nuclear safety, and nascent nuclear arsenals may prove inviting targets for preemptive attack during crises. International and internal violence remain prevalent in many countries, a number of territorial issues remain unresolved, and in some cases certain states do not recognize the legitimacy and sovereignty of their neighbors.

This last concern is of utmost importance. When a country's very existence is threatened, nuclear weapons may begin to seem an appropriate and legitimate tool of foreign policy. Clausewitz stated that there should be a meaningful relationship between military means and political ends; in the eyes of many leaders, the survival of one's country may be one of the few political ends that could justify nuclear means.[4]

THE EFFECTS OF THE OPTIONS ON EXTENDED DETERRENCE

Historically, the United States has maintained nuclear weapons to deter nuclear war. But these weapons were also maintained to deter other countries, including the Soviet Union, from attacking the United States or its allies with conventional weapons. Although the Cold War seems over now, the Soviet Union remains a formidable military power and a volatile political power. Thus, deep cuts in U.S. weapons should not be made without considering their effects on what is sometimes called extended deterrence.

In the past, the Soviet Union has had more conventional forces than the United States and its allies. Compared with the United States, the Soviet Union was also geographically closer to Western Europe, an area of key U.S. concern. Because of these advantages, some analysts have argued that U.S. nuclear deterrence would be effective only if Washington possessed some measure of real or perceived superiority vis-à-vis Moscow. However, under some of the more far-reaching options in this study, the United States might not have any substantial superiority. Not only would it be agreeing to numerical parity in weapons--something that it accepted long ago in the SALT negotiations--but it would be forgoing the development of many qualitative advantages in areas such as bomber technology, submarine-launched ballistic missiles, and large-scale strategic defenses.

Careful studies have reached varying conclusions about the historical importance of nuclear superiority for global deterrence. Too many other factors have been at work to separate out the impact of nuclear weapons on the Berlin, Mideast, and Cuban missile crises, for example, and on Soviet assertiveness in the 1970s as manifested in the

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4. See Carl von Clausewitz, *On War*, edited and translated by Michael Howard and Peter Paret (Princeton: Princeton University Press, 1976), especially pp. 75-89.

invasion of Afghanistan and the "cooperative interventions" with Cuban troops in Angola and Ethiopia.[5] (See Box 6.)

Other considerations suggest that nuclear superiority is no longer important for extended deterrence. First, the superpowers have developed a modus vivendi for competing globally without being drawn into direct conflict with each other. Moreover, the superpowers are unlikely to regain their ideological fervor or competitiveness, even if the current Soviet reform process collapses. Whatever minor benefits the Soviet Union feels it gained by large-scale operations to help Communist regimes to power in Angola, Ethiopia, and Afghanistan are probably viewed as outweighed by the costs: protracted civil wars in some of those countries; an end to detente with the United States in the 1970s and the corresponding U.S. military buildup; estrangement from China, Japan, much of Western Europe, and many other countries over these interventions; and huge fiscal and human costs.[6] President Gorbachev is not the only Soviet leader to have taken stock of these historical lessons.

Many factors are likely to assure stability in Europe, the area where the United States has been most concerned about deterring Soviet aggression. Memories of the destructiveness of World War II, together with standing armies in Europe and the vast respect that the superpowers have held for each other's conventional military capabilities, make conventional deterrence substantial.[7] Moreover, given the importance that both the United States and the Soviet Union accord to their security zones and economic interests in Europe, neither country could threaten the "sphere" of the other without expecting to incur extremely grave risks. Even relatively small strategic nuclear arsenals probably would be more than enough to provide formidable

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[5] See, for example, Richard K. Betts, *Nuclear Blackmail and Nuclear Balance* (Washington, D.C.: Brookings Institution, 1987), pp. 3-16 and 213-233.

[6] See, for example, Jerry F. Hough, *The Struggle for the Third World* (Washington, D.C.: Brookings Institution, 1986), pp. 258-269; Richard H. Ullman, "Ending the Cold War," *Foreign Policy* (Fall 1988), pp. 142-144; Raymond L. Garthoff, *Detente and Confrontation* (Washington, D.C.: Brookings Institution, 1985).

[7] See John Mueller, "The Essential Irrelevance of Nuclear Weapons: Stability in the Postwar World," *International Security* (Fall 1988), pp. 55-68; Richard H. Ullman, *Securing Europe* (Princeton: Princeton University Press, 1991).

BOX 6

The Cold, Cold Seventies: Superpower Relations in the 1970s

Some analysts suggest that aggressive Soviet behavior in the 1970s was a direct consequence of a tilt in the superpower nuclear balance. But many other factors contributed to the Soviet Union's assertiveness during the 1970s, apart from Moscow's attainment of nuclear parity with Washington. Its enhanced military capabilities, in the form of an expanded navy and global basing network, as well as enhanced airlift and sealift capability, gave it the tools to carry out much more direct and large-scale intervention than it previously had been able to do. Frequent Western interventions in the Third World had provided a type of precedent for such superpower activity, which Soviet leaders may have felt entitled to conduct themselves in places such as Angola and Afghanistan. The SALT I agreements on ground rules for U.S.-Soviet competition in the Third World contributed to this mind-set as well, seemingly codifying the superpower status and rights of the Soviet Union.

U.S. retrenchment and passivity at the end of the Vietnam War gave the Soviet Union good reason to think that its activities would be unopposed by the West. Also, Soviet political theorists developed a new doctrine that advocated building strong Communist parties in the Third World whenever possible. These were known as "MLVPs," or Marxist-Leninist Vanguard Parties. Finally, the Soviet Union had not yet learned the danger of provoking a backlash from NATO, China, and Japan as a group. For all of these reasons, the Soviet Union displayed a hubris that had not been witnessed since at least the days of Khrushchev.

Altogether, these historically unique circumstances produced a dangerous revolution in Soviet foreign policy thinking. Fortunately, this ended in the 1980s, as Soviet leaders were disabused of many of their loftier aspirations.[1]

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[1] Raymond L. Garthoff, *Detente and Confrontation* (Washington, D.C.: Brookings Institution, 1985), pp. 289-408; Stephen T. Hosmer and Thomas W. Wolfe, *Soviet Policy and Practice Toward Third World Conflict* (Lexington: D.C. Heath and Company, 1983); Andrzej Korbonski and Francis Fukuyama, *The Soviet Union and the Third World: The Last Three Decades* (Ithaca: Cornell University Press, 1987).

nuclear deterrence against any attempt to change the status quo in Europe, given the strength of superpower political commitments in that theater.[8]

Clearly, one has good reason to hope that many of the recent shifts in Soviet policy reflect more than transitory changes. Nevertheless, it is reassuring to see historical evidence in support of the notion that even hostile states are unlikely to derive much global benefit--if any--from nuclear superiority. Any geopolitical risks involved in far-ranging nuclear arms control, therefore, may be quite modest.

Finally, the strategic forces that would remain under any option discussed here would retain significant deterrent capability for contingencies in various theaters, whether or not they involved the Soviet Union. Missiles would provide the capability of rapid response, and would be especially useful against fixed targets such as depots and transportation infrastructure or slow-moving targets such as ships near shore and major ground-force concentrations; bombers would provide at least some capability to pursue mobile targets.

NUCLEAR ARMS CONTROL AND BROADER FOREIGN POLICY ISSUES

In deciding to go to war against Iraq, President Bush called upon U.S. citizens and other peoples to join in building what he called a "new world order"--a system of international behavior that would replace Cold War tendencies with a system that featured more respect for the rules of international law. Nuclear arms control of the type envisioned in this study's options might be able to play an important role in this regard. It could improve security by sustaining deterrence, while providing incentives for other important types of arms control, perhaps including greater limits on nuclear and missile proliferation. Nuclear arms control could also free up U.S. fiscal resources on the order of $15 billion or more annually, leaving the money for other uses that might contribute more to global economic growth and stability than do nuclear arms.

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[8] See McGeorge Bundy, *Danger and Survival*; Thomas C. Schelling, *Arms and Influence* (New Haven: Yale University Press, 1966), especially chapter 2; Robert Jervis, *The Illogic of American Nuclear Strategy* (Ithaca: Cornell University Press, 1984), especially chapters 5 and 6.

At the same time, however, any reduction in nuclear forces leading to a weakened U.S. deterrent would be an extremely false economy. Nuclear forces must, first and foremost, deter war. Few goals can be more important than that.

APPENDIXES

APPENDIX A

DETAILS OF THE FORCES AND THEIR COSTS

In Chapter IV, a good deal of costing detail was provided, but in the interest of clarity it was somewhat simplified and aggregated. This appendix presents some of the raw data that were used or generated for the costing calculations; these include costs for individual weapons systems, broken into operation and support costs and acquisition costs. In addition, some costs are broken down on a year-by-year basis. First, however, some basic information on selected major weapons systems is presented.

STRATEGIC SYSTEMS

Within each of the three categories of strategic systems--intercontinental ballistic missiles, submarine-launched ballistic missiles, and bombers--the United States generally possesses one or two different systems, and is producing or planning to produce one new system.

Land-based ballistic missiles make up the first category or "leg" of the triad. The oldest intercontinental ballistic missiles are the Minuteman II and Minuteman III missiles, with one and three reentry vehicles carried on each missile, respectively. These missiles were deployed in hardened underground silos in the 1960s and 1970s and in some cases upgraded in subsequent years. In the 1980s, the United States purchased 50 MX missiles, each carrying 10 independent reentry vehicles. The missile was officially redesignated as the "Peacekeeper" and placed in existing Minuteman missile silos. The United States has also undertaken research and development (R&D) concerning the feasibility of placing these missiles on mobile rail cars as an alternative method of basing, though the Administration has terminated plans to carry out this transfer. Furthermore, in recent years, the United States has begun a research and development program for a small single-warhead ICBM (SICBM or “Midgetman”) that could be based in silos or on road-mobile hardened missile launchers. This SICBM remains in the R&D phase today, though President Bush's September 1991 initiative has eliminated research on mobile-basing for this missile.

The second leg of the U.S. strategic triad consists of submarine-launched ballistic missiles (SLBMs). Today's SLBMs are based on Poseidon and Trident submarines. As the newer Trident submarines enter the fleet, the older Poseidon submarines are being retired. The missiles carried on these submarines are designated as Poseidon and Trident I missiles. A new missile, the Trident II, is in production and will gradually become the primary missile on most of the new Trident submarines.

The Trident submarines are also referred to as Ohio class. Several of this type of submarine are under contract today. The Poseidon submarines include the Lafayette, Madison, and Franklin classes. Alternative designations of the Poseidon, Trident I, and Trident II missiles are the C3, C4, and D5, respectively. Ballistic missile submarines are often designated as SSBNs, which stands for subsurface ballistic missile vessel, nuclear powered.

The third leg of the triad consists of strategic bombers. The bomber fleet includes two main classes of aircraft--the workhorse B-52 aircraft, some of which are now more than 30 years old, and the modern B-1 bomber that was deployed in the mid-1980s. These aircraft carry a number of types of munitions with fundamentally different attributes. Both carry free-fall bombs, as well as high-speed, short-range attack missiles (SRAMs) with rocket engines and inertial guidance systems. The B-52 also is equipped to carry subsonic air-launched cruise missiles (ALCMs), and the B-1 may be fitted to carry these munitions in the future as well. (Cruise missiles are essentially small, unmanned aircraft that are designed to be launched outside Soviet airspace, enabling bombers to attack without penetrating Soviet air defenses, whereas SRAMs are designed to be fired within a couple hundred kilometers of their targets.) The United States is now producing more advanced air-launched cruise missiles known as Advanced Cruise Missiles.

Finally, the United States is completing development of the B-2 Stealth bomber and beginning production of that aircraft. Under current Administration plans, 75 B-2 aircraft will be purchased over the next few years.

THEATER SYSTEMS

The options in this study deal not only with strategic nuclear systems that can attack targets at intercontinental range, but also with delivery vehicles and their associated warheads that possess shorter ranges. These systems, capable of threatening targets located in the same theater of military operations in which they are based, are therefore commonly designated as theater weapons.

Theater systems are based among a wide array of naval, ground force, and tactical air force platforms; at any given time, some are deployed forward with combat units, and others are held in reserve at depots in the United States or the Soviet Union.

The diversity in the basing of theater nuclear weapons is matched by the wide range of characteristics they possess. Some have short ranges; examples of this type of weapon are antisubmarine depth charges and nuclear artillery shells, though U.S. and Soviet nuclear artillery are now to be destroyed. Other theater weapons can begin to blur the distinction between strategic and nonstrategic weapons, since they include systems with ranges of more than 1,000 kilometers. These systems include nuclear-armed versions of the sea-launched cruise missile, which is still in production, and tactical aircraft equipped to carry nuclear bombs, such as the Soviet Backfire and some U.S. aircraft.

BALLISTIC MISSILE DEFENSES

The United States is currently developing a system of ballistic missile defenses, which if deployed would not comply with the Anti-Ballistic Missile (ABM) Treaty. Under the Administration's plan, the Strategic Defense Initiative Organization (SDIO) would first develop a system named Global Protection Against Limited Strikes. GPALS is intended to defend the United States against attacks of 100 to 200 warheads that could result from a small accidental or unauthorized launch by the Soviet Union or from attacks by a smaller nuclear power, provided that effective decoys and countermeasures did not accompany these warheads. GPALS would consist of interceptors based in space (probably the small systems known as brilliant pebbles), as well as ground-based interceptors.

While developing and deploying GPALS, the Administration plans to begin developing a more far-reaching system of defenses that it hopes will someday be capable of protecting the United States and its allies from a large-scale nuclear attack. It is assumed here that Phase I of such a system would be deployed by 2006. Phase I would probably consist of space-based and ground-based interceptors designed to intercept about 1,500 incoming warheads. Eventually, there might be another, more capable version of this large system.

COSTS

Tables A-1 through A-7 provide details of the costs of different weapons systems and the various options; the tables include data from the Administration's 1990 plan for comparison with other costs.

TABLE A-1. U.S. AVERAGE ANNUAL NUCLEAR COSTS, 1992-2006 (In billions of 1992 dollars)

	Administration's Plan		Post-START Options			
Cost Category	1990	Current	I. Ban Heavy ICBMs, Limit Defenses	II. Reduce Strategic Warheads to 6,000	III. Reduce Strategic Warheads to 3,000	IV. Reduce Strategic Warheads to 1,000
All Nuclear-Related Activities Except Deployed Strategic Defenses						
Strategic Offense	20.7	15.7	15.5	10.9	7.1	7.0
Theater Offense	1.8	1.5	1.5	1.0	0.5	0
Nuclear Warheads	13.4	13.4	13.2	12.3	11.4	11.1
Nuclear Command, Control, Communications, and Intelligence	10.0	8.0	8.0	7.8	6.8	6.5
Arms Control Compliance and Monitoring	0.2	0.2	0.5	0.8	1.1	1.1
Air Defenses	2.0	2.0	2.0	2.0	2.0	2.0
Strategic Defense Initiative--Research and Tactical Missile Defense Initiative	3.0	3.0	3.0	3.0	3.0	3.0
Subtotal	51.1	43.8	43.7	37.8	31.9	30.7
Deployed Strategic Defenses						
Strategic Defense Initiative--GPALS Only	3.1	3.1	3.1	2.0	1.7	1.0
Strategic Defense Initiative--Phase I	2.2	2.2	0	0	0	0
Subtotal	5.3	5.3	3.1	2.0	1.7	1.0
Total with Deployed Strategic Defenses						
Total	56.4	49.1	46.8	39.8	33.6	31.7

SOURCE: Congressional Budget Office.

NOTE: ICBMs = intercontinental ballistic missiles; GPALS = Global Protection Against Limited Strikes.

TABLE A-2. U.S. ACQUISITION COSTS FOR STRATEGIC FORCES
(In billions of 1992 dollars of budget authority)

Plan or Option	Future Years Defense Program (FYDP) 1992	1993	1994	1995	1996	1997	Total FYDP 1992-1997	Beyond FYDP 1998-2006	Total (1992-2006)
Administration's 1990 Plan	13.4	13.3	14.9	16.5	14.9	12.7	85.7	32.6	118.3
Administration's Current Plan	8.0	7.3	8.1	8.9	7.7	7.0	47.0	26.6	73.6
Administration's Plan with START	8.0	7.3	8.1	8.9	7.7	7.0	47.0	26.6	73.6
I. Ban Heavy ICBMs, Limit Defenses	8.0	7.3	8.1	8.9	7.7	7.0	47.0	26.6	73.6
II. Reduce Strategic Warheads to 6,000	7.3	6.7	7.4	5.7	4.4	3.5	35.0	9.2	44.2
III. Reduce Strategic Warheads to 3,000	1.9	1.7	1.9	1.9	1.5	1.3	10.2	2.1	12.3
IV. Reduce Strategic Warheads to 1,000	1.9	1.7	1.9	1.9	1.5	1.3	10.2	2.1	12.3

SOURCE: Congressional Budget Office, from data provided by the Department of Defense.

NOTE: ICBMs = intercontinental ballistic missiles.

TABLE A-3. U.S. OPERATION AND SUPPORT COSTS FOR STRATEGIC FORCES (In billions of 1992 dollars of budget authority)

Plan or Option	Future Years Defense Program 1992	1993	1994	1995	1996	1997	Steady State[a]
Administration's 1990 Plan	7.0	6.5	6.0	5.9	6.0	6.2	10.4
Administration's Current Plan	6.8	6.0	5.3	5.1	5.2	5.4	7.7
Administration's Plan with START	6.8	6.0	5.2	4.9	5.0	5.1	7.5
I. Ban Heavy ICBMs, Limit Defenses	6.8	6.0	5.2	4.9	5.0	5.1	7.5
II. Reduce Strategic Warheads to 6,000	6.8	5.4	4.3	3.8	3.7	3.8	4.0
III. Reduce Strategic Warheads to 3,000	6.5	5.3	4.0	3.5	3.2	2.9	2.4
IV. Reduce Strategic Warheads to 1,000	6.5	5.3	4.0	3.4	3.1	2.9	2.4

SOURCE: Congressional Budget Office, from data provided by the Department of Defense.

NOTE: ICBMs = intercontinental ballistic missiles.

[a] Once the small ICBM is fully deployed.

TABLE A-4. DETAILS OF U.S. AVERAGE ANNUAL COSTS FOR STRATEGIC OFFENSE, 1992-2006 (In billions of 1992 dollars)

	Administration's Plan			Post-START Options			
Activity	1990	Current	With START	I. Ban Heavy ICBMs, Limit Defenses	II. Reduce Strategic Warheads to 6,000	III. Reduce Strategic Warheads to 3,000	IV. Reduce Strategic Warheads to 1,000
Procurement	7.9	4.9	4.9	4.9	2.9	0.8	0.8
Operation and Support	7.8	6.3	6.1	6.1	4.2	3.2	3.2
Modifications	2.5	2.0	2.0	2.0	1.5	1.0	1.0
Tankers	1.5	1.5	1.5	1.5	1.3	1.1	1.0
Basic Research and Development	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total	20.7	15.7	15.5	15.5	10.9	7.1	7.0

SOURCE: Congressional Budget Office.

NOTE: ICBMs = intercontinental ballistic missiles.

TABLE A-5. U.S. AVERAGE UNIT PROCUREMENT COSTS OF SELECTED NUCLEAR SYSTEMS, EXCLUDING COSTS OF DEPARTMENT OF ENERGY WARHEADS (In millions of 1992 dollars)

Weapons System	Average Unit Procurement Cost
MX Missile (Silo)	100
Small Intercontinental Ballistic Missile	30
Trident Ohio-Class Submarine	1,400
Trident D5 Missile	30
Tomahawk Sea-Launched Cruise Missile	2
B-2 Bomber	540
B-1 Bomber	200
ACM Air-Launched Cruise Missile	5

SOURCE: Congressional Budget Office, from Department of Defense documents.

NOTE: Current B-2 bomber unit procurement costs are roughly $700 million, but they are expected to decline in future years.

TABLE A-6. U.S. OPERATION AND SUPPORT COSTS FOR SELECTED STRATEGIC SYSTEMS
(In millions of 1992 dollars of budget authority)

Weapons System	Cost Per Primary Missile, Aircraft, or Submarine Authorized
Missiles	
Minuteman	1.5
MX (Silos)	2.6
Aircraft	
B-52	10.4
B-1B	14.7
Submarines	
Trident	45.1
Poseidon	86.7

SOURCE: Congressional Budget Office, using data from the Defense Resources Model.

TABLE A-7. U.S. STRATEGIC FORCE INVENTORIES UNDER CBO'S ASSUMED 1990 ADMINISTRATION'S PLAN (At the beginning of year, in units of delivery vehicles)

Weapons System	Future Years Defense Program						Steady
	1992	1993	1994	1995	1996	1997	State[a]
Intercontinental Ballistic Missile Force							
MX in Silos	50	40	30	20	10	0	0
MX in Rail Garrison	0	10	20	30	40	50	50
Minuteman II	450	450	450	450	450	450	450
Minuteman III	500	500	500	500	500	500	500
Small Intercontinental Ballistic Missile	0	0	0	0	0	12	500
Ballistic Missile Submarine Force							
Trident	12	13	14	15	16	17	23
Poseidon	22	16	10	7	7	6	0
Bomber Force							
B-2A	0	3	6	13	19	26	132
B-1B	97	97	97	97	97	97	97
B-52	156	140	124	108	95	95	95

SOURCE: Congressional Budget Office.

a. Once the small intercontinental ballistic missile (SICBM) is fully deployed.

APPENDIX B

EXCHANGE CALCULATIONS

What are the formulas and assumptions that drive the model of nuclear exchanges used in this study, and what are the results of the exchange calculations? The model is based primarily on standard formulas and methods that previous CBO studies have used. It is intended to be simple, yet capture the most essential elements of a nuclear war. The myriad uncertainties involved in predicting the results of a nuclear war make the results of any model approximate at best: a more complex model would not necessarily improve the accuracy of a simple model.

ELEMENTS OF THE EXCHANGE MODEL

The following section discusses the ways in which different types of weapons systems might be attacked in a first strike.

Silo-Based ICBMs

The variables that are critical to assessing the survivability of intercontinental ballistic missiles (ICBMs) based in silos are the magnitude of the nuclear explosion (its yield), the distance that the warhead explodes from the silo, and the silo's hardness (its resistance to nuclear explosions). The standard formula that expresses the probability of one warhead destroying the missile (usually referred to as the single-shot probability of kill, SSPK) as a function of these three quantities is:

$$\mathrm{SSPK} = 1\text{-}\exp[\text{-}\mathrm{LR}^2/1.44\mathrm{CEP}^2] \qquad (1)$$

where CEP is the circular error probable for the warhead, a measure of the accuracy defined as the radius of the circle (in meters here) that encompasses the landing points of 50 percent of all warheads aimed at a given target.[1] LR is the lethal radius of the nuclear warhead for a detonation at the optimum height for maximizing blast effects on the ground, which is a function of the size of the attacking warhead and the hardness of the silo to nuclear explosions. It can be calculated by the following formula:[2]

$$LR = 460(Y/H)^{\frac{1}{3}} \qquad (2)$$

where LR is the lethal radius in meters, Y is the yield of the attacking warhead measured in megatons, and H is the silo hardness in thousands of pounds per square inch (psi).

Because CEP is squared in Equation 1, small improvements in CEP cause a much larger improvement in SSPK than similar increases in yield or decreases in hardness, one of the reasons the United States has put such strong emphasis on improving accuracy of the MX and D5 missiles. The Soviet Union is behind the United States in accuracy and therefore is forced to use much larger warheads to attain the same SSPKs, although this disadvantage is offset somewhat because the United States believes that it has softer silos than the Soviet Union (2,000 psi vs. 5,000 psi).

So far this discussion has assumed that the missile and warhead would work perfectly, or have a reliability of 100 percent. To account for imperfect reliability, the expression for the SSPK above can be modified to give the overall probability of kill for one warhead, PK(1):

$$PK(1) = R(SSPK) \qquad (3)$$

where R is the reliability of the missile and warhead system, which is the product of the reliability of the warhead itself, the reliability of the missile, and the ability of the missile controllers to launch the missile. This product or reliability does not include an estimate of the reliability of the national command and control system above the level of the missile controllers.

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[1] This formula is based on the standard expression for a nuclear burst at optimum height for destroying hardened targets on the ground in Lynn E. Davis and Warner R. Schilling, "All You Ever Wanted to Know About MIRV and ICBM Calculations But Were Not Cleared to Ask," *The Journal of Conflict Resolution* (June 1973), p. 211.

[2] Harold Feiveson and Frank N. von Hippel, "The Freeze and the Counterforce Race," *Physics Today* (January 1983), p. 44.

Hardened silos are often assumed to be targeted with more than one warhead to increase the probability that the missile in the silo will be destroyed. The two-warhead probability of kill, PK(2), can be calculated from the probability that the silo survives the first warhead. The probability of surviving the first warhead, PS(1), is 1-PK(1) = 1-R(SSPK). If the two warheads do not interfere with each other, the two-warhead probability of survival is simply the product of the probability of survival for each warhead:

$$PS(2) = PS(1) \times PS(1) = PS^2(1) \tag{4}$$

Thus, the two-warhead probability of kill can be expressed as:

$$PK(2) = 1-PS(2) = 1-PS^2(1) = 1-(1-R(SSPK))^2 \tag{5}$$

Similarly, the probability of kill after the "nth" warhead, PK(n), is $1-(1-R(SSPK))^n$.

Silo-Based ICBMs: Fratricide

Equation 5 assumes that the warheads arriving at the target would not affect each other as they exploded. However, given the radiation and blast from the explosion and the debris that would be hurled into the air if a warhead exploded near the surface, there is a strong possibility that incoming warheads would be affected--either being destroyed or having their accuracy degraded by the first warhead to explode near the target. This phenomenon is known as fratricide.[3] If two or more warheads arrived at the same point at the same time, whichever went off first would destroy the others--its x-rays, neutrons, shock waves, or fireball could all be lethal to other warheads in the vicinity.

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[3] Matthew Bunn and Kosta Tsipis discuss fratricide in "Ballistic Missile Guidance and Technical Uncertainties of Countersilo Attacks," Report Number 9, Program in Science and Technology for International Security, Department of Physics, Massachusetts Institute of Technology (August 1983). A less comprehensive treatment can be found in Bunn and Tsipis, "The Uncertainties of a Preemptive Nuclear Attack," *Scientific American* (November 1983).

When targets separated by about 10 to 20 kilometers (km) are attacked, which is typical spacing for silos in ICBM fields, the debris from the first attacking warheads can create a cloud of debris that covers the missile field. The debris in this cloud can destroy an incoming reentry vehicle (RV), which would be traveling at speeds exceeding 5 kilometers per second. If the warheads were staggered by tens of seconds, the debris cloud formed by the first explosion could destroy subsequent warheads. A second RV could safely enter the cloud only after the largest debris had fallen from the cloud, from 10 minutes to 30 minutes after the first attack.

The degree to which fratricide would affect subsequent warheads is not known with certainty because the 1963 Limited Test Ban Treaty between the United States and the Soviet Union prohibits nuclear testing above ground, thereby eliminating the possibility of realistic testing. As a result of the uncertainty about the effects of fratricide, the approach taken in this study is to look at the two extreme cases: the case without fratricide and the case with complete fratricide. The actual effect of fratricide most likely lies somewhere between these two bounds. Nuclear explosions from attacks on nearby silos and the clouds of dust and debris that these explosions thrust into the atmosphere can also cause fratricide, but this model does not explicitly account for this effect except to acknowledge it as a cause of further uncertainty for an attacker.

Under the assumption of complete fratricide, the subsequent warheads would be destroyed if the first warhead detonated reliably. If the first warhead failed to explode because either the warhead or the missile malfunctioned, the second warhead could explode over the target. If this warhead failed also, the third warhead could explode over the target, and so on.

Thus, it is easiest to think of the probability of kill as the product of a reliability term, which depends on the number of warheads aimed at a target, and a single-shot probability of kill term, which is independent of the number of warheads because only one warhead could detonate over the target. Consequently, in the case of complete fratricide, multiple warheads aimed at the same target would improve the probability that one warhead would explode reliably, but would not improve the probability of kill for a single exploding warhead.

Complete Fratricide. In the complete fratricide case, the probability that the target is destroyed by the second warhead is expressed as the sum of the probability that the first warhead destroyed the target and the probability that the second warhead survives and explodes reliably on the target. Thus, the probability that a missile in its silo does not survive both warheads can be expressed as

$$PS^{f}2 = R(SSPK) + (1\text{-}R) \times R(SSPK) \qquad (6)$$

where the first term (R(SSPK)) is the probability that the first warhead detonates and destroys the target, and the second term is the probability that the second warhead survives (1-R) times the probability that the second warhead detonates and destroys the target (R(SSPK)). Therefore, the probability that a missile in its silo survives two warheads subject to complete fratricide is

$$PS^{f}(2) = 1 - R(SSPK) + (1\text{-}R) \times R(SSPK) \qquad (7)$$

In general, the probability that a silo survives n warheads subject to complete fratricide is

$$PS^{f}(n) = 1 - \sum_{i=1}^{n} (1\text{-}R)^{i-1} R(SSPK) \qquad (8)$$

Comparison of a Complete Fratricide and No-Fratricide Calculation. An example best illustrates the difference between the no-fratricide case and the fratricide case. Consider a Soviet SS-18 warhead attacking a U.S. silo hardened to 2,000 psi. From Table B-1, one can see that the warhead is assumed to have a CEP of 150 meters (m) by the year 2006 and a yield of 500 kilotons (kt). Against the 2,000-psi silo, the lethal radius would be 290 m and its SSPK would be .93, as would its overall probability of kill, PK(1), assuming perfect reliability. Since the SS-18's actual reliability probably would be no more than 85 percent, its actual PK(1) would be no higher than .79.

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TABLE B-1. ASSUMED CHARACTERISTICS FOR UNITED STATES AND SOVIET WEAPONS SYSTEMS, CIRCA 2006

Weapon	Reliability	Missile Throw-weight (Kilograms)	Yield per Warhead (Kilotons)[a]	Circular Error Probable (Meters)[b]	Lethal Radius (Meters)[c]	Single-Warhead Kill Probability (R(SSPK))	Two-Warhead Kill Probability: No Fratricide	Two-Warhead Kill Probability: Fratricide
United States								
MM III	.80	1,100	170	200	150	.26	.45	.31
MM IIIA	.80	1,100	335	200	185	.36	.59	.43
MX	.85	3,600	300	100	180	.76	.94	.87
SICBM	.85	600	500	150	215	.65	.88	.74
D5/Mark 5	.80	2,400	475	150	210	.59	.83	.71
D5/Mark 4	.80	2,400	100	150	125	.31	.52	.36
C4	.80	1,400	100	300	125	.09	.17	.11
ALCM	.85	n.a.	200	100	155	.69	.90	.79
SLCM	.85	n.a.	200	100	155	.69	.90	.79
SRAM	.85	n.a.	200	350	155	.11	.21	.13
ACM	.85	n.a.	200	100	155	.69	.90	.79
SRAM II	.85	n.a.	200	100	155	.69	.90	.79
Bomb	.90	n.a.	1,000	150	270	.81	.96	.88
Soviet Union								
SS-24	.85	3,600	100	150	170	.50	.75	.58
SS-25	.85	1,400	550	150	300	.80	.96	.91
SS-18	.85	7,600	500	150	290	.79	.95	.90
SS-19	.80	3,400	550	150	300	.75	.94	.90
SS-17	.80	2,700	500	150	290	.74	.93	.89
SS-N-20	.80	1,800	200	350	215	.18	.33	.22
SS-N-23	.80	1,800	200	350	215	.18	.33	.22
SS-N-18	.75	1,100	200	350	215	.17	.31	.21

SOURCE: Congressional Budget Office based on: Congressional Budget Office, *Modernizing U.S. Strategic Offensive Forces: Costs, Effects, and Alternatives* (1987); Duncan S. Lennox, ed., *Jane's Strategic Weapon Systems* (Surrey, U.K.: Jane's Information Group, 1990); International Institute for Strategic Studies, *The Military Balance 1989-1990* (London, U.K.: Brassey's, 1990) and *1990-1991* edition.

NOTES: MM = U.S. Minuteman missile; SICBM = small intercontinental ballistic missile; ALCM = air-launched cruise missile; SLCM = sea-launched cruise missile; SRAM = short-range attack missile; ACM = Advanced Cruise Missile; SS = U.S. designation for Soviet surface-to-surface ballistic missiles; SS-N = U.S. designation for Soviet surface-to-surface naval missiles; n.a. = not applicable.

a. CBO assumes that by 2006, Soviet SS-N-20 and SS-N-23 warhead yields increase to 200 kt from their current estimated values of 100 kt as the Soviet Union takes advantage of the extra throwweight on its downloaded SLBMs to deploy larger warheads.

b. CBO assumes that by 2006, Soviet ICBMs all will have a circular error probable (CEP) of 150 meters, and that Soviet SLBMs will have CEPs of 350 m. Today, the SS-24 and SS-25 are estimated to have CEPs of 200 m; the SS-18, 250 m; the SS-19, 300 m; the SS-17, 400 m; the SS-N-20, 500 m; the SS-N-23, 500 m; and the SS-N-18, 900 m. The single-warhead kill probabilities are .34, .67, .52, .40, .24, .06, .06, and .03, respectively. U.S. missiles are assumed to remain at 1991 accuracies.

c. The lethal radius is the maximum distance at which a detonation of the warhead in question would provide enough overpressure to destroy a missile silo. For these calculations, U.S. silos are assumed to withstand up to 2,000 pounds per square inch overpressure and Soviet silos are assumed to withstand up to 5,000 pounds per square inch. Lethal radius is calculated for detonation to maximize overpressure on the ground.

Without fratricide, a second warhead would increase the probability of kill: PK(2) would be .95, and a third warhead would increase the probability of kill even more, to PK(3) = .99. With complete fratricide, however, a second warhead would increase the probability of kill, $PK^f(2)$, to only .90, which is considerably less than a second warhead gives in the case without fratricide. A third warhead would increase the probability of kill, $PK^f(3)$, to .92, just slightly above the PK^f for two warheads, and slightly below the PK(1) with perfect reliability. The most striking difference between the cases with and without fratricide is that without fratricide, the probability of kill can approach 100 percent as the number of warheads per target increases even with imperfect reliability, whereas with fratricide, the probability of kill can never exceed the SSPK. Because the chance that fratricide could affect incoming warheads would increase as the number of warheads per target increased, all silo attacks assume that no more than two warheads would be allocated to each silo.

Throughout this study, U.S. silos are assumed to be hardened to 2,000 psi and Soviet silos are assumed to be hardened to 5,000 psi.

To account for potential modernization in Soviet nuclear forces by the year 2006, CBO has assumed that the Soviet Union improves the accuracy (CEP) of its ballistic missiles and takes advantage of the unused throwweight on the downloaded SS-N-20 and SS-N-23 to increase the yield of the warheads on these missiles. ICBM accuracy improves to 150 m, SLBM accuracy improves to 350 m, and warhead yield on the two downloaded missiles increases to 200 kt from the present yield of 100 kt.

Although the kill probability results in Table B-1 are presented with two significant figures, not all of the numbers that went into the calculation are known with this degree of precision. In reality, the reliability of weapons in an actual nuclear exchange could be different from that in the controlled environment of the test range: warhead yields could be variable, CEPs for untested trajectories could be worse than for known test-range trajectories, and silos could be harder or softer than estimated by testing.

With or without fratricide, today the United States could destroy the missiles in Soviet silos with high probability, largely because of the extreme accuracy of U.S. MX and D5 ballistic missiles. With the improvements in accuracy assumed to occur by 2006, the Soviet ICBMs could be just as lethal.

Road-Mobile ICBMs: Barrage Attack

Road-mobile missiles are designed to be dispersed over a large area during a nuclear attack. This wide dispersion makes them difficult to target, improving their chances of survival. Because the missiles would be widely dispersed and their exact locations probably unknown to the attacker, the attacker would probably have to resort to a barrage attack--an attack where enough warheads were used to produce lethal blasts over the entire surface of the dispersal area. The formula that approximates the lethal radius of a warhead in meters for a given yield and mobile missile hardness is:[4]

$$LR = Y^{1/3} 1685 p^{k} \qquad (\text{for } 10 \leq p < 100 \text{ psi}) \qquad (9)$$

where Y is the yield in kilotons, p is the target hardness in pounds per square inch, and k is a constant that depends on the target hardness.[5] The Soviet SS-25 mobile missile launcher has not been hardened against nuclear effects; therefore, the SS-25 system is assumed to be destroyed with overpressures of 10 psi--twice the peak overpressure that would damage most trucks.[6,7] The value of k for a system with a hardness of 10 psi would equal -0.620. The lethal radius calculation is based on a "cookie-cutter" approach, whereby any launchers inside the circle defined by the lethal radius are assumed to be destroyed because the overpressure would be at least 10 psi, and any launchers outside the circle would be left unscathed. The lethal radius for a 500-kt warhead against a 10-psi launcher would be 3.2 km, and the lethal area of the circle would be 32.3 km^2.

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[4] Joshua M. Epstein, *The 1988 Defense Budget* (Washington, D.C.: Brookings Institution, 1987), p. 28, note a. This formula was derived by fitting a curve to Defense Nuclear Agency data.

[5] This equation differs from Equation 2 because, whereas Equation 2 is optimized for destroying hard targets by getting maximum overpressure over a small area on the ground, Equation 9 is optimized for barrage attacks by varying the height of burst to maximize the size of the lethal radius on the ground.

[6] "Breakout, Verification and Force Structure: Dealing with the Full Implications of START," House Armed Services Defense Policy Panel, May 24, 1988, p. 34.

[7] See Samuel Glasstone and Philip J. Dolan, *The Effects of Nuclear Weapons*, 3rd ed. (Department of Defense and the Energy Research and Development Administration, 1977), pp. 189-192 and 221-225.

This equation for lethal radius has not, however, accounted for two other important considerations. They arise because, to barrage a large area, many warheads must be used, and their circles of destruction must be made to blanket the entire area where mobile launchers could be found.

The first factor, which would degrade the capabilities of barraging warheads relative to the idealized calculations above, stems from the non-zero CEPs of warheads. Again using the cookie-cutter approach to simplify the calculations, if one assumes that every warhead would miss its target in an unknown direction by exactly the CEP, it is necessary to reduce the distance between aim points by twice the CEP because one warhead might land one CEP to one side of its intended aim point and an adjacent warhead might land one CEP to the other side of its aim point. For example, if one could target warheads 1 km apart using the idealized equation, a CEP of 100 m would require that the warheads be targeted only 800 m apart. The corrected equation for the lethal radius becomes:

$$LR' = LR - CEP \qquad (10)$$

The second factor is the result of geometry. This problem arises from trying to cover a rectangular area with small circles: all the gaps cannot be covered without overlapping the circles. Therefore, for a successful barrage, the circles of destruction must overlap, in effect wasting some of the destructive capability of the warheads. Using a hexagonal pattern for the aim points, the most efficient pattern, geometry indicates that 1.2 times as many warheads should be used than if the area to be barraged were simply divided by the lethal area of each warhead.[8]

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[8] An alternative attack strategy would avoid overlap to make the most of the destructive area at the cost of leaving gaps in coverage.

Taking these corrections into account, the number of warheads required to barrage an area A is:

$$1.2A/\pi(LR\text{-}CEP)^2 \qquad (11)$$

The Soviet Union has already deployed the road-mobile SS-25 missile, and the United States has been developing the road-mobile small ICBM. On September 27, 1991, President Bush announced that the United States would discontinue its road-mobile basing program for the small ICBM. Instead, the missile will only be deployed in silos. Therefore, only the Soviet Union is assumed to deploy road-mobile missiles.

The Soviet Union is assumed to keep its road-mobile missiles at, or near, their bases during day-to-day alert. Under START and all four post-START options, the Soviet Union would be required to keep its mobile missiles in restricted areas not larger than 25 km^2, each containing no more than 10 mobile missile launchers. CBO assumes that the missiles at each restricted area, upon warning of an attack, would scatter with an average speed of 30 miles per hour (45 kilometers per hour), increasing the radius of the area of uncertainty by 12.5 meters per second (m/s). The attacker could barrage these mobile missile bases and their surrounding areas to destroy the missiles as they try to escape. Submarine-launched ballistic missiles (SLBMs) presumably would be used in the attack because of their short flight times. During generated alert, the mobile missiles are assumed to be dispersed in an area too large to barrage effectively; therefore, mobile missiles presumably would not be attacked in the generated-alert case.

Rail-Mobile ICBMs

Soviet rail-mobile missiles are assumed to be kept in garrisons during day-to-day alert, parked in relatively soft bunkers. During a severe crisis, the trains would be dispersed over large portions of the national rail network. During a nuclear exchange, the missile launchers would be easy prey if they had not been dispersed, with essentially 100 percent vulnerability to any nuclear detonation because of the softness of their bunkers. Only the imperfect reliability of the attacking missiles and warheads would keep their vulnerability below 100 percent. If the launchers had enough warning before the attack arrived to disperse, their probability of survival would increase dramatically.

The scenario for a day-to-day alert used in this study assumes that just a few warheads would destroy all rail-mobile missiles in their garrisons. The generated-alert scenario assumes that the trains would have enough time, at least several hours, to disperse over a large enough portion of the national rail network that they could not be effectively barraged. A barrage attack against rail-mobile missiles is a linear variant of the area barrage mentioned above against road-mobile missiles.

Ballistic Missile Submarines

Three separate issues arise in assessing the vulnerability of ballistic missile submarines (SSBNs): the vulnerability of SSBN ports and any submarines that might be in them; the vulnerability of SSBNs in protected tunnels; and the vulnerability of SSBNs in the open sea. SSBNs in port are essentially 100 percent vulnerable to nuclear attack: the submarines themselves are soft, and they are not in shelters. The Soviet Union has built protective tunnels for some of its SSBNs, but the United States has not. Soviet tunnels may enhance the survivability of the submarines within them, but although these tunnels may be as hardened as ICBM silos, the rubble from nuclear explosions could easily block the tunnel entrances.[9] Therefore, submarines in ports and in tunnels would be quite vulnerable to U.S. ballistic missile warheads.

SSBNs alone in the open sea are far more likely to survive because the combination of their quietness and the vast areas of the ocean in which they operate make detecting them difficult. But SSBNs can be followed as they leave port in some cases, and "tailed" over a period of time. U.S. SSBNs are elusive enough that they are thought to have been rarely tailed by Soviet attack submarines, so they are very sur-

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9. Tom Stefanick, *Strategic Antisubmarine Warfare and Naval Strategy* (Lexington: Lexington Books, 1987), p. 34.

vivable platforms. However, U.S. attack submarines can, in theory, trail Soviet SSBNs because Soviet submarines are noisier and U.S. passive sonar technology is better. Consequently, to protect its ballistic missile submarines, the Soviet Union often deploys them in bastions in the Barents Sea or the Sea of Okhotsk protected by nuclear and diesel-electric attack submarines, ships, aircraft specializing in antisubmarine warfare, and mines. The modern Soviet submarine-launched ballistic missiles--the SS-N-20 and the SS-N-23--have the range to strike the United States from within these bastions. Because U.S. SSBNs are so elusive and Soviet SSBNs would be likely to be deployed in bastions, all those submarines at sea are assumed to survive.

Today, the United States has 67 percent of its Trident submarines and 55 percent of its older Poseidon submarines at sea at any one time. The Soviet Union has a markedly different deployment doctrine: today, only about 15 percent to 25 percent of its SSBNs are at sea during day-to-day alert. Despite these low at-sea rates, the Soviet Union has demonstrated an excellent capability to deploy its submarines quickly from port, indicating that perhaps 67 percent of Soviet SSBNs could be put to sea during a generated alert. These deployment rates are assumed constant for all the options considered in this study.

Bombers and Bomber Bases

Bombers on the ground would be extremely vulnerable to nuclear attack because the bombers are soft (of 1 to 4 psi hardness), and the runways are easily destroyed. There are four solutions to this vulnerability: place the bombers on runway alert so that they can take off after first warning of an attack and before the first warheads arrive; keep the bombers flying at all times so that they can fly away from the base when an attack is first detected; disperse the bombers to enough airfields that it would be difficult to attack all of them quickly enough before some escaped; and develop many secondary dispersal bases for use during a crisis.

The United States has traditionally placed a significant portion of its strategic warheads on bombers. Concerned about their vulnerability to a Soviet attack, it has adopted a combination of all four approaches at various times throughout the Cold War. From 1958 to 1968, the United States kept a portion of its bomber fleet in the air at all times, but the improved survivability of the ICBM and submarine forces, improved warning systems, and cost and safety considerations led to the demise of this policy.[10] After 1968, the United States maintained the survivability of the bomber force by keeping one-third of its bomber fleet on runway alert at more than 10 bases, ready to take off in as little as 6.5 minutes after the first Soviet missile launch was detected. On September 27, 1991, President Bush ended the peacetime alert of U.S. bombers during a major revision of U.S. operating policy for nuclear forces in response to the post-coup environment in the Soviet Union. Hence, for all postures except that for the forces as of early 1991, U.S. bombers are assumed to be off alert during day-to-day conditions.

In contrast, the Soviet Union has never demonstrated much concern for the survivability of its bomber fleet: no indications are evident that Moscow keeps any of its bombers on runway alert, making the entire fleet vulnerable to a surprise attack. This situation could reflect the small portion of the Soviet arsenal that is based on bombers, or could indicate little Soviet concern about surprise attack, or could indicate a belief that warheads surviving on ICBMs and submarines would be enough to deter the United States. Because of this low Soviet alert rate, this study assumes that each Soviet bomber base is targeted by only four warheads in a U.S. first strike during a day-to-day alert.

During a crisis, when both sides are assumed to keep bombers on runway alert, an attacker could not destroy the other side's bomber fleet with a few warheads per base, although these warheads would destroy all bombers that remained on the ground. If the attacker wanted to destroy the bombers that were flying away from the base at the time of the attack, it would have to barrage the area over which the bombers had dispersed, an area that is a function of the missile flight time, the time it takes to detect the launch and warn the bombers, the time it takes from warning until the aircraft take off, and aircraft speed.

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[10] Bruce G. Blair, *Strategic Command and Control: Redefining the Nuclear Threat* (Washington, D.C.: Brookings Institution, 1985), p. 33.

The dispersal area is actually a volume of airspace because the aircraft can climb to various altitudes. To completely barrage this volume, warheads would have to be stacked on top of each other because, with some bombers flying high and others flying low, their altitudes could differ by more than the lethal diameter of the warhead. In this model, CBO simplified the scenario by barraging an area rather than a volume.

This simplification is justified for two reasons: first, most of the bombers that would be destroyed are close to their base, 30 km or less from the end of their runways, where they could not gain enough altitude to escape the effects of an airburst from most Soviet SLBM warheads. Second, in the first 75 km or so from their bases, bombers gain more survivability by getting away from the base as quickly as possible than by climbing because aircraft can fly faster in level flight than while climbing. Therefore, it would be reasonable to assume that the United States kept its bombers relatively low (below 10,000 ft.) while they dispersed from their bases.

CBO has developed a model that estimates the survivability of U.S. bombers by relating the area in which the bombers would be dispersed to the area that the Soviet Union could barrage with its SLBM warheads. The same model is used for the U.S. attack on Soviet bombers, except that a slight correction is made for superior U.S. SLBM accuracies.

The equations that drive the model are quite similar to the equations used for mobile missile barrage except that the lethal radius equation is adjusted to account for the bombers being destroyed by air bursts rather than optimized near-surface bursts.[11] Because the dispersal area and barrage area are functions of time, the relationship between them critically depends on how much megatonnage per second the SSBNs could deliver on each base, a quantity called equivalent-megaton flux (EMT flux) here.[12] Because SSBNs can only launch their

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[11] See Glasstone and Dolan, *The Effects of Nuclear Weapons*, Figure 3.72, p. 109. The authors acknowledge the assistance of Eric Graben of the University of Virginia on this issue.

[12] Because the blast radii of nuclear weapons scale with the cube root of the yield, equivalent megatonnage is used to compare the effects of warheads and to express the aggregate area that multiple warheads could cover in a barrage attack.

(Continued)

missiles one at a time, the attacker can only increase the flux on a given number of bases by increasing the number of submarines involved in the attack.

Table B-2 shows the results of this model for a variety of EMT fluxes and missile flight times.[13] To use it, compute the EMT flux per base and the SLBM flight time for a given scenario. Then find the number of surviving bombers per base from the table in the cell defined by the appropriate flux and flight time. Only bombers that are on alert are assumed to survive; others are assumed to be destroyed on the ground.

Thus, the numbers in the table reflect the maximum number of bombers that would survive per base if all those bombers were on alert. For example, if one were to assume an attack on 10 bases with 15 Soviet SSBNs, each one carrying missiles with ten 100-kt (or 0.22 EMT from the EMT conversion formula in note 12) warheads and each submarine able to launch one missile every 15 seconds, one missile would be launched every second and one warhead would arrive at each base every second (10 warheads per second and 10 bases). Since each warhead delivers about .22 EMT, the flux would be .22 EMT/second/base, or approximately .20 EMT/second/base. If the missile took 420 seconds to reach the bomber base, no bombers would survive (see Table B-2). However, if the flight time were 720 seconds, up to 18 alert bombers would survive per base. Obviously, if there were fewer than 18 bombers on alert at the base, only that smaller number would survive.

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12. Continued

EMT (equivalent megatonnage) can be calculated by the following formula:

$$\mathrm{EMT}_i = Y_i^{2/3} \text{ if } Y_i \leq 1 \text{ MT}$$

and the total EMT for more than one warhead can be expressed as:

$$\mathrm{EMT} = \Sigma \mathrm{EMT}_i$$

[13] The calculation assumes the following: it would take 90 seconds from the time the first submarine-launched ballistic missile left the water until warning was sounded at bomber bases, and another five minutes before the first bomber took off; B-2, B-1B, and B-52 bombers could be destroyed by overpressures of 4 pounds per square inch; there would be 15 seconds between bomber takeoffs; and bombers would fly out in a random pattern to ensure the uncertainty in their position. The same parameters are used for Soviet bombers during a U.S. attack.

Table B-2 also shows that the total EMT required per base--that is, the sum of the EMT for all the warheads used to barrage the base--would be three EMT in both cases. Thus, it would take roughly fourteen 100-kt warheads per base to destroy the maximum number of bombers in this scenario.

The scenarios in this study include several assumptions. For the early 1991 forces, one-third of U.S. bombers are on runway alert during day-to-day conditions, but for the Administration's current plan and all other options, no bombers are on runway alert during day-to-day conditions. For all options, 95 percent of the U.S. fleet can be placed on runway alert during a crisis. No Soviet bombers are on day-

TABLE B-2. U.S. BOMBER SURVIVABILITY PER BASE UNDER BARRAGE ATTACK

SLBM Flight Time (Seconds)	EMT per Second per Base[a]							
	0.07	0.13	0.20	0.27	0.40	0.53	0.67	0.80
	Surviving Bombers per Base[b]							
360	0	0	0	0	0	0	0	0
390	0	0	0	0	0	0	0	0
420	0	0	0	0	0	0	0	0
450	2	1	0	0	0	0	0	0
480	4	3	2	1	0	0	0	0
510	6	5	4	3	2	0	0	0
540	8	7	6	5	4	2	1	0
570	10	9	8	7	6	4	3	1
600	12	11	10	9	8	6	5	3
630	14	13	12	11	10	8	7	5
660	16	15	14	13	12	10	9	7
690	18	17	16	15	14	12	11	9
720	20	19	18	17	16	14	13	11
750	22	21	20	19	18	16	15	13
780	24	23	22	21	20	18	17	15
810	26	25	24	23	22	20	19	17
840	28	27	26	25	24	22	21	19
870	30	29	28	27	26	24	23	21
900	32	31	30	29	28	26	25	23

(Continued)

SOURCE: Congressional Budget Office.

NOTES: SLBM = submarine-launched ballistic missile; EMT = equivalent megatonnage.

a. Numbers in column headings indicate EMT flux (EMT per second per base). Numbers in table indicate the maximum number of alert bombers that would survive per base for corresponding EMT flux and time of flight. If fewer bombers were on alert per base than the maximum number of surviving bombers found in the table, only the smaller number of alert bombers would survive.

to-day alert and roughly 90 percent are on alert during a crisis. The escaping bombers would stay below 10,000 feet for the first 75 km of their flight, and the Soviet Union would place its submarines just off the Atlantic and Pacific coasts. Both U.S. and Soviet submarines can launch one missile every 15 seconds. The United States currently uses 12 bomber bases, 2 within 500 km of the coast, 4 around 1,200 km from the coast, and 6 around 2,000 km from the coast; SLBM flight times to these bases would be 6 minutes or less, 9 minutes, and 12 minutes, respectively, assuming minimum-energy trajectories.

In order to reflect the Cheney proposal to close bases, announced April 1, 1991, the United States uses nine bases in the hypothetical

TABLE B-2. Continued

SLBM Flight Time (Seconds)	EMT per Second per Base[a]							
	0.07	0.13	0.20	0.27	0.40	0.53	0.67	0.80
				Total EMT Required per Base				
360	0	0	0	0	0	0	0	0
390	0	0	0	0	0	0	0	0
420	1	2	3	4	6	8	10	12
450	1	2	3	4	6	8	10	12
480	1	2	3	8	12	8	10	12
510	1	2	3	8	12	32	30	24
540	1	2	3	8	12	32	40	48
570	1	2	3	8	12	32	40	72
600	1	2	3	8	12	32	40	72
630	1	2	3	8	12	32	40	72
660	1	2	3	8	12	32	40	72
690	1	2	3	8	12	32	40	72
720	1	2	3	8	12	32	40	72
750	1	2	3	8	12	32	40	72
780	1	2	3	8	12	32	40	72
810	1	2	3	8	12	32	40	72
840	1	2	3	8	12	32	40	72
870	1	2	3	8	12	32	40	72
900	1	2	3	8	12	32	40	72

b. Based on 15-second SLBM launch rate, 15-second bomber takeoff rate, and a 6.5-minute delay between the detection of the first SLBM launch and the first bomber takeoff (90 seconds from first SLBM launch to first warning at bomber bases and 5 minutes to get first bomber off ground at each base), 350-m CEP, a 4-psi bomber hardness, and a packing factor of 1.2. The 350-m CEP is for Soviet SLBMs, assumed to be improved by the year 2006. Because the U.S. SLBMs are more accurate (CEP is 150-m), slightly fewer Soviet bombers would survive per base. Uses CBO bomber flyout profiles that were derived from public sources.

Administration plan, the START plan, and Options I and II: two bases within 500 km of the coast; two around 1,200 km from the coast; and five around 2,000 km from the coast. For Options III and IV, only the five inland bases are assumed to be used. The Soviet Union currently has six bomber bases--four around 1,200 km from the coast, one around 2,000 km from the coast, and one about 3,000 km from the coast. Options III and IV assume that the Soviet Union uses only four bases to reflect the smaller number of bombers in its force. Depressed SLBM trajectories, which would have significantly shorter flight times than minimum-energy trajectories, have not been included in these scenarios because the Soviet Union has not demonstrated this capability to date. Given the short flight times of depressed-trajectory missiles--about six minutes for a range of 2,000 km with a twice-minimum-energy missile--virtually all U.S. bombers would be destroyed on the ground if the Soviet Union launched such an attack.

The Soviet SLBM attack on U.S. bomber bases assumed in this study is in many ways a worst-case scenario because it assumes that the Soviet Union would be able to surreptitiously deploy 15 to 20 ballistic missile submarines just off the coast of the United States. Given the sophistication of U.S. sonar nets, the relative noisiness of Soviet submarines, and the Soviet Union's demonstrated preference for keeping its submarines deployed in bastions near its own coasts, such a scenario is not likely. However, a similar scenario for a U.S. first strike may well be within the capabilities of the United States because its submarines are quieter, they are deployed regularly off European and Pacific coasts, and the Soviet Union does not have a sophisticated sonar net in those areas.

Command, Control, Communications, and Intelligence

Command, control, communications, and intelligence (C^3I) assets would be essential for coordinating a retaliatory strike. The U.S. C^3I system has several main elements, and presumably the Soviet system does too--the vast majority of them vulnerable to attack. It is this vulnerability that makes the outcome of any nuclear exchange uncertain and difficult to model with accuracy.

The Persian Gulf War illustrates how critical command, control, communications, and intelligence can be: in the early phases of the war, the United States and its allies were able to destroy many of the critical nodes of Iraq's C^{3}I system, severely degrading Iraq's capability to coordinate its air and ground forces. The same sort of thing could happen in a nuclear war: in addition to counterforce targets, a first strike could concentrate on the command and control assets that would be required to launch a retaliatory strike. These assets--with their antennas, fixed command posts, and communications lines--tend to be vulnerable to nuclear attack.

This situation presents the United States with a paradox: even though large portions of the U.S. forces could survive a first strike, these forces would be useless if the C^{3}I system were unable to give an order to launch. One should not take the nuclear parallel with Iraq's C^{3}I collapse too far, however: it is one thing simply to order tens or hundreds of missiles to launch, but it is quite another to conduct a complex ground campaign or air defense. In this regard, the Persian Gulf War provides another useful example--Iraqi leaders managed to transmit the orders to launch Scud missiles repeatedly despite their tattered C^{3}I system.

The command and control system can be made less vulnerable in several ways: more redundancy can be built into the system, command posts can be put on mobile platforms like aircraft or mobile ground stations, and launch orders can be delegated to field commanders upon warning of an attack. The United States has carried out all three of these measures to some degree. Nevertheless, because the vulnerabilities cannot be removed completely, uncertainty about the C^{3}I system's performance persists.

The exchange calculations used in this study are based on the assumption that, although the command and control systems would be degraded during a first strike, the system would be redundant enough and the launch orders simple enough that most surviving forces could be launched properly in a retaliatory second strike, and coordinated to attack a given target set.

THE EXCHANGE MODEL: ASSUMPTIONS AND ATTACK PLAN

The equations for each of the different types of attacks described above have been used as part of the overall attack plan in this exchange model. In addition to the equations, several other important pieces of information are needed to develop a plan. First is the plan that directs how the attacker's warheads will be allocated to the various targets. The first strikes modeled here are essentially counterforce attacks, whose goal would be to disarm the defender, thereby increasing one's relative power and minimizing the damage at home from retaliation.

The plan of attack is conceptually simple: one would attack all silos, bomber bases, mobile missile bases and garrisons, and submarine bases. All silos would be targeted with two warheads to improve the probability of kill.[14] Bomber bases are assumed to be targeted with four warheads in those cases in which the bombers would not be on alert (both the U.S. and the Soviet bombers during day-to-day conditions), or in which the bases are close enough to the coast that the bombers would not have time to escape (U.S. bases at Griffiss, New York, and Fairchild, Washington). When SLBM flight time and alert rates would allow some bombers to take off before a base was attacked, the attacker is assumed to barrage the area surrounding the base according to the model for bomber survivability. Road-mobile missiles are assumed to be garrisoned during peacetime, and in all START and post-START postures to stay within a treaty-limited area of 25 km^2 per base during peacetime, with no more than 10 missiles per area.

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14. Attacking warheads are allocated by exhausting the entire stock of a given type, beginning with the most lethal and then using progressively less capable systems, except for the Soviet SS-25, some of which are always held in reserve. The Soviet Union is assumed to use forces in the following order: SS-18, SS-25, SS-19, SS-17, SS-24. The United States is assumed to employ its forces in the following order: MX, SICBM, D5 (with all warheads assumed to be 475-kt Mark 5s), Minuteman IIIA, Minuteman III.

    Those silos containing the most lethal types of systems, weighted by number of warheads, are attacked by the most capable systems. Thus, the Soviet Union is assumed to attack MX silos with its best systems, then the Minuteman III, and then the SICBM; similarly, the United States is assumed to attack the SS-18 with its most capable missiles (MX and SICBM), and the SS-24, SS-19, SS-17, SS-13, SS-11, and SS-25 with less capable missiles. All silos would be attacked at roughly the same time.

During day-to-day alert, the attacker is expected to take advantage of the small size of the deployment areas by barraging each base and the surrounding area as the mobile missiles disperse. During a serious crisis, these missiles would disperse outside those areas, creating an area of uncertainty too large for the attacker to barrage effectively; therefore, the missiles are assumed to be invulnerable in this case. Tracking down these missiles with satellites and bombers is assumed to be beyond the capability of either the United States or the Soviet Union by the year 2006. Rail-mobile missiles would remain in

TABLE B-3. RESULTS OF EXCHANGE CALCULATIONS FOR THE UNITED STATES

		Remaining Warheads After U.S. First Strike		Remaining Warheads After Soviet First Strike	
Plan or Option	Initial U.S. Warheads	Day-to-Day Alert, No Fratricide	Generated Alert, Fratricide	Day-to-Day Alert, No Fratricide	Generated Alert, Fratricide
Forces as of Early 1991	12,850	10,020	9,820	4,830	8,240
Administration's Plan and Variation					
Administration's Current Plan	11,534	9,020	9,500	2,400	5,290
Administration's Plan with START	10,455	8,830	8,510	2,360	5,200
Post-START Options					
I. Ban Heavy ICBMs, Limit Defenses	10,455	8,830	8,510	2,500	5,410
II. Reduce Strategic Warheads to 6,000	6,000	4,570	4,890	2,350	4,460
III. Reduce Strategic Warheads to 3,000	3,000	1,950	2,420	890	2,210
IV. Reduce Strategic Warheads to 1,000	992	480	680	300	760

SOURCE: Congressional Budget Office.

NOTE: ICBMs = intercontinental ballistic missiles.

their garrisons during day-to-day alert, where they would be targeted by four warheads each. During generated alert, these missiles would disperse over the national rail network, a track length too large to barrage effectively.

A group of about 100 other important targets would be attacked by four warheads each. This target set would include ballistic missile submarine bases (three in the United States and six in the Soviet Union), bomber bases that are not going to be barraged, roughly 50

TABLE B-4. RESULTS OF EXCHANGE CALCULATIONS FOR THE SOVIET UNION

		Remaining Warheads After Soviet First Strike		Remaining Warheads After U.S. First Strike	
Plan or Option	Initial Soviet Warheads	Day-to-Day Alert, No Fratricide	Generated Alert, Fratricide	Day-to-Day Alert, No Fratricide	Generated Alert, Fratricide
Forces as of Early 1991	11,586	8,760	9,080	2,060	5,590
Administration's Plan and Variation					
Administration's Current Plan	12,087	9,590	9,380	1,290	4,730
Administration's Plan with START	7,583	5,380	5,210	570	3,240
Post-START Options					
I. Ban Heavy ICBMs, Limit Defenses	7,583	5,380	5,210	570	3,240
II. Reduce Strategic Warheads to 6,000	5,998	4,920	4,740	490	2,930
III. Reduce Strategic Warheads to 3,000	3,000	2,180	1,970	470	2,000
IV. Reduce Strategic Warheads to 1,000	1,000	400	400	420	830

SOURCE: Congressional Budget Office.

NOTE: ICBMs = intercontinental ballistic missiles.

ports and airfields in each country, up to 10 rail-mobile bases, and a few key command and control facilities.

The Soviet attack is assumed to proceed in the following manner: the SSBNs deployed close to U.S. coasts would launch their attack on the bomber bases first, to maximize the element of surprise and minimize the warning that U.S. bombers would have. Shortly after the beginning of the SLBM launch, the Soviet Union would launch its ICBMs against U.S. silos and submarine bases. It would take roughly 30 minutes for the first ICBM warheads to arrive at their targets, but the United States is assumed to ride out the attack, not launching its ICBMs before the Soviet warheads arrived.

The United States would conduct a similar attack plan if it were to attack the Soviet Union first except that U.S. SLBMs would barrage Soviet mobile missiles during day-to-day conditions. The attack scenario here assumes perfect timing by the attacker: the SLBM attack is well coordinated in order to catch bombers on the ground. It also assumes that the attacker uses some of its most survivable systems in the first strike, like the Soviet SS-25 and the U.S. D5, in order to inflict maximum damage. However, an attacker might not want to diminish its second-strike capability and therefore might hold some of these forces in reserve rather than expend them during the first strike.

RESULTS OF THE EXCHANGE CALCULATIONS

At least 21 percent and perhaps more than 75 percent of U.S. warheads would survive a Soviet first strike. In contrast, as few as 8 percent and as many as 83 percent of Soviet warheads might survive a first strike by the United States. Table B-3 on page 163 presents the results of the exchange calculations for the United States. Table B-4 presents the results for the Soviet Union. Results of the exchange calculations are discussed further in Chapter V.

APPENDIX C

EFFECTIVENESS OF MISSILE DEFENSES

This study has not analyzed defenses in depth, largely because of the complexity of the subject, the highly classified nature of much key data, and the uncertainties intrinsic to any discussion of technologies that are revolutionary and unproven. Nevertheless, it is useful to organize some basic concepts for reference. This discussion treats missile defenses, and in particular the Global Protection Against Limited Strikes (GPALS) system proposed by the Bush Administration.

In the pages that follow, simple analysis using basic principles of physics is able to set some meaningful limits on the performance of missile defense systems.

The proposed Global Protection Against Limited Strikes architecture includes roughly 1,000 space-based "brilliant pebbles" and roughly 750 ground-based long-range interceptors as its vehicles for destroying missiles and warheads. How do these numbers translate into the purported capability of the system to intercept up to 200 ballistic missile warheads? In the following calculation, CBO postulates a limited strike by 20 SS-18 missiles carrying a total of 200 warheads and all launched from one small geographic region.

SPACE-BASED INTERCEPTORS

Consider first the space-based brilliant pebbles, which are small, self-propelled interceptors that would home in on individual missiles.[1] To analyze the capabilities of brilliant pebbles, one must make several assumptions about their performance. CBO assumes for purposes of this calculation that the net reliability of a brilliant pebble--the product of the reliabilities of tracking and guidance systems as well as destruction mechanisms--would be 80 percent. Another assumption is that the pebbles would fly at an altitude of about 500 kilometers (km)--the distance above the Earth's surface at which they would make most of their intercepts--and in circular orbits with periods of roughly 90 minutes. (For simplicity, the analysis below assumes pebbles are in a polar orbit. Because of the all-latitude threat posed by ballistic missile submarines and by non-Soviet threats, it would not be possible to place pebbles in orbit over only the temperate latitudes.) A final assumption is that the pebbles' terminal speed would be about 6 kilometers per second.

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[1] Below an altitude of 100 kilometers or so, pebbles probably would be worthless as a result of air resistance and the inability of their sensors to see through heated atmospheric gases. Thus, missiles flying below this altitude could underfly them. See David C. Wright and Lisbeth Gronlund, "Outsmarting Brilliant Pebbles" (Federation of American Scientists, Washington, D.C., 1991).

This analysis is based on the assumption that brilliant pebbles probably would have to intercept missiles before the missiles dispensed their individual warheads and decoys. The Strategic Defense Initiative Organization, though hoping to find a way for the pebbles to discriminate among warheads in midcourse, admits that the mission is difficult and may not prove feasible.

The missile used for the following calculation--the Soviet SS-18--would finish its boost phase about five minutes after launch.[2] (Because this missile burns relatively slowly, and because it carries 10 warheads, the brilliant pebbles may have greater capability of countering SS-18 warheads than of countering other types of Soviet missile warheads.) Assuming it would take one minute for detecting missile launch and beginning the acceleration of the pebble, there would be four minutes for the pebble to pursue the missile at full speed. At the speed of 6 km/s, the pebble could move from its initial orbit by nearly 1,500 km in this time.

What are the chances that a given pebble would be in the right place to intercept an outgoing SS-18? Answering this question exactly is difficult. But the problem can be simplified, to good approximation,

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2. Reportedly, the boost phase of next-generation missiles could be completed as soon as one minute after launch, at an altitude of about 100 km. Brilliant pebbles would not be able to operate at such a low altitude. Such rockets have not yet been developed or produced, though the Soviet Union would have a very strong incentive to do so if the United States deployed a large number of space-based defense systems. But rockets with burn times at least somewhat shorter than the SS-18 already do exist.

to a two-dimensional problem. When an SS-18 missile leaves the atmosphere, it can be imagined to be found somewhere on the surface of a sphere surrounding the Earth that is concentric with the Earth's surface. This sphere, located 500 km above the Earth's surface and surrounding the entire planet, has a surface area of about 600,000,000 square kilometers. (Actually, an SS-18 could reach only some regions of this sphere's surface, since SS-18 missile fields are found only within the territory of the Soviet Union and not throughout the globe. But, as noted earlier, brilliant pebbles would have to be deployed at all latitudes because of the threats posed by submarine-launched missiles and non-Soviet missiles.)

In four minutes, a pebble with the characteristics given above could fly out over a circle with area equal to roughly 6,500,000 km^2. This area represents about 1 percent of the surface of the sphere concentric with the Earth's surface. Thus, the pebble would have roughly a 1 percent chance of being in the right region to attempt intercept.[3] For a constellation of 1,000 brilliant pebbles, as anticipated under the GPALS system, about 10 would therefore be expected to be in the right place to attempt to intercept a given SS-18.

If a group of SS-18 missiles were launched simultaneously from the same missile field, and directed toward approximately the same destination, all the missiles would leave the atmosphere in roughly the same place and at roughly the same time. Thus, only 10 pebbles would be available to attempt intercept. If eight of the pebbles worked properly, up to 80 SS-18 warheads could be countered in this way--assuming that each pebble attacked a different SS-18.

GROUND-BASED INTERCEPTORS

Under the GPALS architecture, ground-based missiles would be deployed at six sites. Even this number of sites would not be capable of

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[3] The authors acknowledge the assistance, through personal communication, of Dan Fenstermacher of Princeton University's Center for Energy and Environmental Studies and Frances Lussier of the Congressional Budget Office.

TABLE C-1. CAPABILITIES OF VARIOUS DEFENSE SYSTEMS AGAINST LIMITED ATTACKS BY 20 SS-18 MISSILES
(In numbers of warheads destroyed)

	Capability		
System	Space-Based	Ground-Based	Total
GPALS	80	40	120
GPALS Minus Pebbles	0	40	40
One-Half GPALS, Minus Pebbles	0	20	20
One-Eighth GPALS, Minus Pebbles	0	5	5

SOURCE: Congressional Budget Office.

NOTE: GPALS = Global Protection Against Limited Strikes.

defending all coastal regions against missiles launched from submarines deployed near U.S. coasts, but they could provide significant protection against accidental launch from more distant locations.[4]

In any case, for an engagement within the capability of the interceptor's acceleration, speed, and range, back-of-the-envelope calculations are informative. Assuming 80 percent reliability per rocket and 80 percent destruction probability per successful rocket, an interceptor would have a 64 percent chance of intercepting a warhead. Unless sequential "shoot-look-shoot" techniques could be used--which is unlikely, given the speed at which the engagement would occur--it would be necessary to use three interceptors per warhead to have a 95 percent chance of successful interception per warhead. Thus, the effective exchange ratio would be three to one.

A single base of about 125 interceptors thus could be saturated by about 40 warheads. (Were an attack evenly distributed over the United States, saturation could be accomplished by about 250 warheads.) Thus, a GPALS system's ground-based component probably should be thought of as having the theoretical capability to intercept 40 warheads. This discussion presupposes that the Soviet Union would not be able to jam or destroy U.S. radars and that the United States would be able to discriminate Soviet decoys from reentry vehicles. These assumptions remain Herculean, given the current state of defense technologies.

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[4] For information on missile flight time as a function of range, see, for example, Harold Feiveson and Frank N. von Hippel, "The Freeze and the Counterforce Race," *Physics Today* (January 1983), p. 42.

Combining these numbers with those for brilliant pebbles gives a net intercept capability of around 120 warheads for the GPALS system. These calculations scale linearly with the numbers of pebbles and interceptors. (However, these calculations apply only to the case of SS-18 missiles.) Thus, Table C-1 can be constructed to show the approximate capabilities of different defense systems.

APPENDIX D

SOVIET FORCES

The Soviet offensive strategic forces used in this study for each option appear in Table D-1.

TABLE D-1. SOVIET STRATEGIC OFFENSIVE FORCES IN 2006 UNDER ALTERNATIVE FORCE POSTURES

Plan or Option	SS-18	SS-24		SS-25	SS-17	SS-19	Delta[a]	
		Silo	Rail				III	IV
Forces as of Early 1991[c]	308 (10)	56 (10)	33 (10)	288 (1)	47 (4)	300 (6)	14 (7)	7 (4)
Assumed Soviet Plan and Variation								
Current Soviet Plan	308	150	36	715	0	200	14 (3)	10 (4)
Soviet Plan with START	154	60	36	715	0	0	6	10
Post-START Options								
I. Ban Heavy ICBMs, Limit Defenses	0	214	36	715	0	0	6	10
II. Reduce Strategic Warheads to 6,000	0	115	36	600	0	0	6	10
III. Reduce Strategic Warheads to 3,000	0	50	36	500	0	0	0	10 (3)
IV. Reduce Strategic Warheads to 1,000	0	0	0	500	0	0	0	10 (1)

(Continued)

SOURCES: Congressional Budget Office based on Department of Defense, *Soviet Military Power, 1990* (1990); International Institute for Strategic Studies, *The Military Balance 1990-1991* (London: Brassey's, 1990); Duncan S. Lennox, ed., *Jane's Strategic Weapon Systems* (Surrey, U.K.: Jane's Information Group, 1990).

NOTES: The numbers in parentheses indicate the number of warheads on each launcher. Unless otherwise indicated, the number of warheads per launcher remains constant as one descends in any single column.

ICBMs = intercontinental ballistic missiles.

TABLE D-1. Continued

Plan or Option	Typhoon[b]	Bear-H	Blackjack	Deployed Launchers	Deployed Warheads	Throw-weight (10^6kg)
Forces as of Early 1991[c]	6 (10)	75 (8)	21 (24)	2,519	11,586	5.7
Assumed Soviet Plan and Variation						
Current Soviet Plan	6	130	70	2,113	12,087	5.6
Soviet Plan with START	6 (6)	130	70	1,541	7,583[d]	3.2
Post-START Options						
I. Ban Heavy ICBMs, Limit Defenses	6	130	70	1,541	7,583[d]	2.6
II. Reduce Strategic Warheads to 6,000	6	130	50	1,307	5,998	2.1
III. Reduce Strategic Warheads to 3,000	6 (3)	100	0	966	3,000	1.6
IV. Reduce Strategic Warheads to 1,000	0	85 (4)	0	745	1,000	1.0

a. Each Delta submarine carries 16 missiles. The Delta III carries the SS-N-18 missile, and the Delta IV carries the SS-N-23 missile.

b. Each Typhoon submarine carries 20 SS-N-20 missiles.

c. Other current Soviet systems, not shown in the tables include: 326 SS-11s, 40 SS-13s, 192 SS-N-6s, 280 SS-N-8s, 12 SS-N-17s (all are single-warhead missiles), and 85 Bear G bombers carrying an average of two warheads apiece. These systems are assumed to be retired for all other force structures.

d. The number of START-countable warheads is 5,973 for the Soviet START force and Option I. On October 5, 1991, President Gorbachev announced that the Soviet Union would further reduce its START-constrained forces after full implementation of the treaty. Because the details of this plan were not available when this study went to press, these changes were not incorporated into this study.

U.S. GOVERNMENT PRINTING OFFICE : 1991 0 - 304-653 QL 3